The ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

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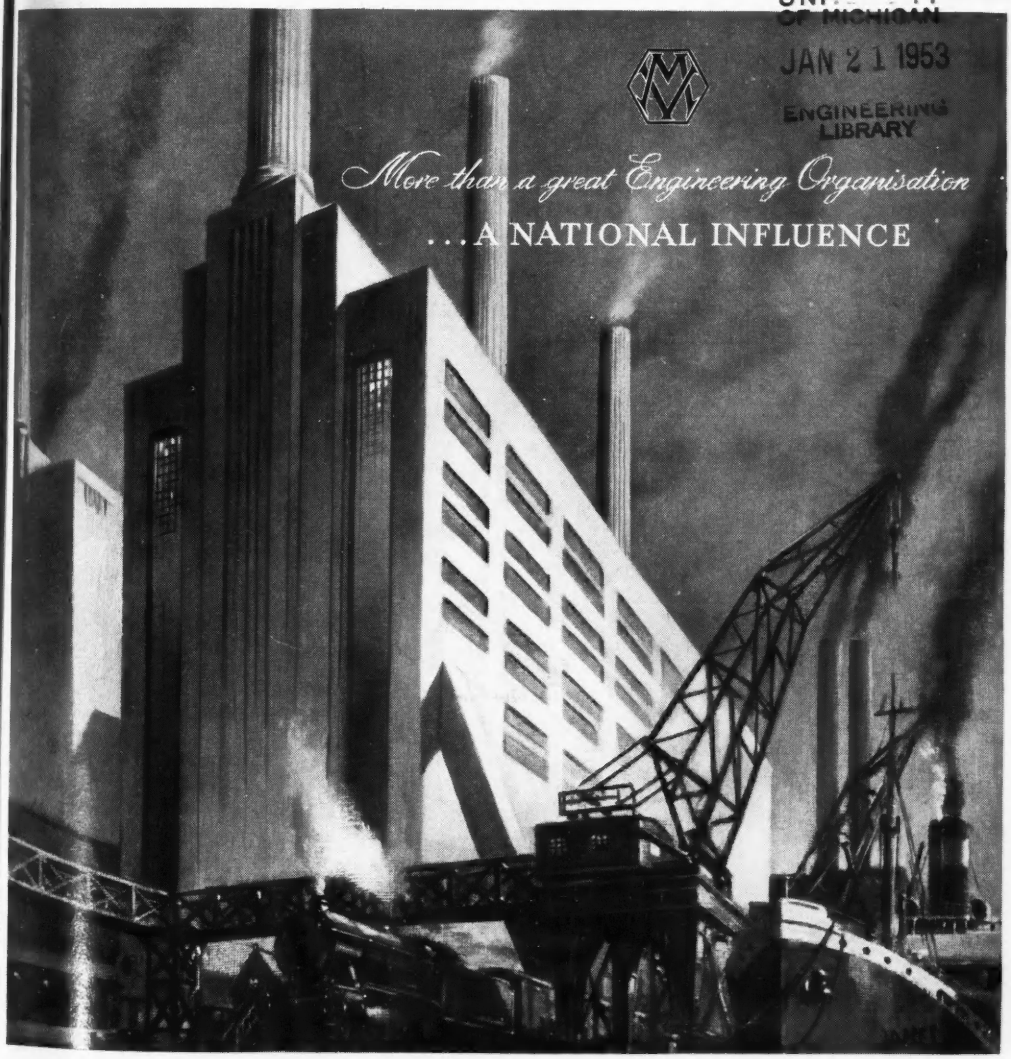

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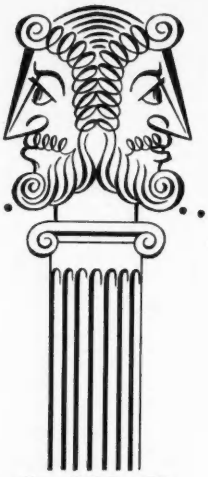

looking back... ...looking forward

The Roman God Janus (the keeper of the door between the old year and the new, from whose name the word January originated) was depicted as having two faces—one to survey the past and the other to look ahead into the future.

There is a deep significance in such symbolical portraiture, for it is our experience that to look back on one's achievements in the year that has passed should represent a challenge and a determination to do even better in the year that lies ahead.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *HOT RADIOGRAPHY*

When making welds of considerable depth, radiographic inspection for flaws as the weld progresses would ensure the discovery of faults in time and in many cases would eliminate the necessity of removing the entire joint weld. The main obstacle to such a procedure, of course, is the waste of time incurred in waiting for the weld to cool sufficiently, as industrial X-ray film is vulnerable to temperatures higher than 100° F. Moreover, a long process of post-heating to relieve internal stresses may be required before controlled cooling can be commenced. After radiographing the cold weld, many more hours of preheating may be necessary before welding can be resumed. The development of a technique to take radiographs while the material is still quite hot now makes it possible to take radiographs without having to cool the material. It is claimed that in certain cases the new technique reduces by some 55 per cent the total time required to weld pipe joints in high-temperature steam piping. In order to make it possible to place the X-ray film in position while the metal is still hot, a water-cooled jacket is provided, which is placed between the metal and the film. In the case of a pipe weld, it consists of two hollow cylinder sectors hinged at one end and fitted with wing nut fasteners at the other. Piping connections provide inlet and outlet for the cooling water. Hollow raised sides of the jacket help to maintain an even temperature distribution along the surface which comes into contact with the film cassette. Flexible cassettes containing the film fit snugly between the raised edges of the jacket and are held in place with heavy rubber retaining bands. A source of gamma radiation is placed at the centre of the pipe and penetrates the weld.

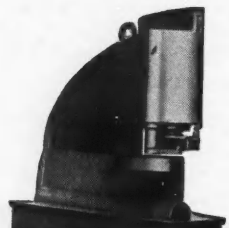
● *LEAD-CLAD STEEL AND COPPER*

The resistance of lead to corrosion, especially by sulphuric acid, has made it an important construction material for the chemical industries. Lead has, however, certain disadvantages which limit its usefulness. It has low strength and is not very resistant to vibration, and fatigue failures occur rather frequently in the presence of temperature cycles. Lead is also unsuitable for vacuum operation unless the thickness is made so great as to make the vessel uneconomical. Attempts to improve the properties of lead by alloying have not yielded completely satisfactory results, particularly for some of the newer processes which require materials to withstand elevated temperatures, or vacuum operations which may be subjected to vibration. In order to overcome these shortcomings, methods for the bonding of lead to steel have been developed. The product combines the corrosion resistance of lead with the strength of steel and is capable of withstanding high vacuum under vibrational conditions at temperatures within 100° F of the melting point of lead. In addition to this, lead-clad steel resists temperature changes much better than lead alone because the lead cladding expands and contracts with the steel and is continuously supported. The process is applicable to the lining of tanks, pipes, valves and fittings and to covering steel pipe, copper tubing and other metals. In order to produce a satisfactory clad surface, a method of pouring the lead upon the steel has been developed. In this process, the steel surface is pickled to remove oxides, and cleaned and molten lead is poured on the surface to be clad. For the lining of pipes, slightly undersize lead tubing is placed in the cleaned pipe and heated and expanded with steam pressure to form the bond.

● *WIRE ABRASION TESTER*

Abrasion resistance is probably the most important property of the insulation of an enamelled magnet wire. Wire enamel must have good abrasion resistance so that extremely careful handling is unnecessary during apparatus manufacturing processes and the insulation will retain its initial dielectric qualities in service. Hence, abrasion resistance is the most frequently measured property. Properly measured, abrasion resistance will evaluate the physical hardness and toughness of a new enamel. On established enamels already in production, abrasion resistance indicates whether or not the enamel is properly baked and so provides a most important manufacturing control test. For some ten years past, a scrape abrasion tester of the oscillating type has been used for the testing of wire enamel of the vinyl acetal type. However, it has been necessary to use the results with caution because of the wide range of values which it may give in tests made in different locations around the periphery of a wire and along its length. A new abrasion tester, termed the " increasing load wire abrasion tester,"

Shear PROFIT



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has now been developed, which gives the required greater accuracy. In this apparatus the wire is tested under a constantly increasing load. The load at the time of failure is taken as a measure of abrasion resistance. Again the test must be made in different planes about the wire in order to measure the effects of variations in film thickness and hardness. It has been found that this load-at-failure varies less from test to test than does the number of strokes-to-failure at constant load.

● *AIR CONTROL OF TEST ENGINE*

In conducting single-cylinder engine investigations, it is common practice to operate under naturally aspirated conditions and to measure the air consumption of the engine by means of a conventional orifice-type airflow meter. However, experience has indicated that this type of meter will not measure accurately the air consumption of a single-cylinder engine under all operating conditions. In addition, air consumptions, observed power outputs, and octane requirements of naturally aspirated single-cylinder engines vary continually with changing atmospheric conditions. Measurement of airflow with a conventional orifice meter is based on the principle of determining the velocity of the air through the orifice by measuring the pressures upstream and downstream from the orifice. However, in a single-cylinder engine, pulsations occur in the downstream pressure owing to the periodicity of the opening of the intake valve and the reciprocating motion of the piston. As a result of these pressure pulsations, the calibration of an orifice meter installed on a single-cylinder engine may be invalidated, and erroneous airflow measurements obtained. As a result of the difficulty involved in trying to eliminate the pressure pulsations, research workers decided to employ a method which is unaffected by pulsations. The method of measurement selected was based on the principle of critical flow of a gas through a convergent nozzle. It was found that with the use of such a nozzle, the air consumption could be measured with an accuracy of 1 per cent under all operating conditions, as compared with errors as large as 20 per cent with the use of conventional orifice meters.

● *EMBRITTLEMENT OF HEAT-RESISTING STEELS*

The phenomenon of embrittlement of steels due to heating at moderately high temperatures for extended periods of time is well known. The fact that the addition of stress can accelerate this condition is a more recent discovery. Data on this latter effect are not available in sufficient quantity to permit of formulating exact conclusions on the effects of stress, temperature, and time on the embrittlement of alloy steels. The embrittlement of heat-resisting steels when subjected to long-time heating was first evidenced by the failure of boiler flange bolts. Although such bolts are generally designed with large factors of safety based on short-time, high-temperature properties, premature failures are frequently encountered. These failures are normally at regions of stress concentration after operation at temperatures of 500° C for 3,000 to 12,000 hours. In most cases, the impact energy of the entire bolt is reduced considerably after only a few hours at high temperature. The steels most readily embrittled are chromium-nickel-molybdenum and chromium-nickel steels. The Cr-Mo steels are relatively free from embrittlement effects. The impact properties of the Cr-Ni-Mo steels can be greatly increased by a reheat treatment. The major portion of the embrittlement, when it is large, results from heating alone. Furthermore, a steel not embrittled by heating is also not significantly affected by the addition of cyclic stresses. The investigation of a number of stress-rupture specimens of various steel types embrittled at 932° F and reheated indicates that the hardness remains practically constant, except for Cr-Ni-Mo steels which exhibit a continuous decrease. The impact strength reveals a progressive embrittlement and a recovery after sufficiently long times to rupture.

● *REDUCING RESIDUAL STRESSES BY THERMAL SHOCK*

A novel method for the reduction of residual stresses produced by the rapid cooling or quenching of metal parts has been proposed. The inventor explains that at the moment of quenching the stresses produced depend upon the temperature gradient and coefficient of expansion of the metal and also on the elastic modulus at the temperature in the region where the stress exists. Additionally, if the stresses developed in any region exceed the elastic limit, deformation occurs which leads to a modification of the stress system. In point of fact, it is only when the elastic limit is exceeded in certain regions at the moment of quenching that, on cooling, residual stresses remain in the piece. The novel method of reducing residual stresses in metal bodies that have been rapidly cooled or quenched consists in subjecting them to such thermal shock as will establish a temperature gradient through the material which is approximately the reverse of the temperature gradient induced during quenching. This method is illustrated by a case in which supercharger rotors of aluminium alloy of 10¼ in. diameter and 2 in. hub length were thermal shock treated. The pieces had been solution treated for two hours at 530° C and quenched in water at 70° C. As a standard of comparison, another specimen, not treated by the new method, was aged at 170° C for 16 hours. Shock treatment for 20 seconds in a salt bath at 350° C and subsequent quenching at 70° C and afterwards ageing at 70° C for 16 hours at 170° C resulted in a 50 per cent reduction of the residual stresses and no appreciable reduction in hardness.

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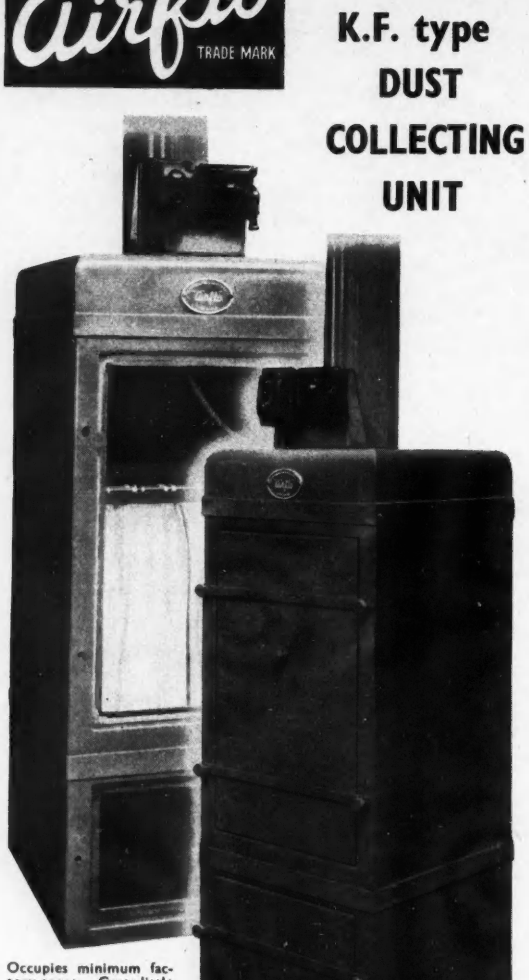

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● *PROPOSED SINGLE VALVE OTTO ENGINE*

The main problem to be solved in the quest for internal combustion engines of higher efficiency is to increase the operating pressures and to lower both operating temperatures and heat losses. Considerable progress has been made in the past towards the solution of these problems, and two-valve engines have reached about 30 per cent thermal efficiency. How much still remains to be done may be gauged from a recent forecast that with a single valve engine approximately 40 to 50 per cent efficiency will be reached. The solution to higher engine efficiency, therefore, would seem to lie in the development of a single valve design where the single valve serves for both inlet and exhaust and reduces the valve temperature to at least one-half at full load and speed. The valve will operate in conjunction with a sliding sleeve distributor in series which changes from exhaust to inlet manifold at top dead centre, but is not exposed to compression or combustion. There is thus only one port which enters the combustion chamber in the centre, and the combustion chamber has therefore perfect shape. The single valve can be 50 per cent larger than if two valves were present. As the valve temperature will not exceed 600° F, the employment of higher compression will be permissible. Compression ratio and dilution in two valve engines are interrelated, and existing limits could only be exceeded by resorting to a different grade of fuel. In the single valve engine, however, these two factors are not tied together, and can be so proportioned that a ten to one compression ratio can be used without leaded fuel as the correct percentage of CO_2 drawn back from the distributor valve will prevent detonation.

● *CASTING CEMENTED CARBIDE PARTS*

In the manufacture of cemented carbide articles such as cutting tool tips, wear parts, dies and form cutting tools, the customary procedures comprise the methods of cold pressing, hot pressing, and extrusion. Cold pressing comprises compacting the hard metal carbide powdered materials under a pressure of approximately 2 to 30 tsi, presintering and mechanically working with cutting tools or grinding wheels to produce the final desired shape. Hot pressing comprises compacting hard metal carbides in powder form in a mould with the simultaneous application of heat and pressure to produce a fully sintered carbide body. These methods make it possible to produce a large variety of simple and fairly complicated shapes, but cannot be applied to highly complicated shapes, particularly such having curved and re-entrant boundary surfaces. A technique has now been evolved which allows the casting of such parts by mixing the powdered hard metal carbide with an organic casting vehicle. This mixture is then cast into a wax, glue, or other suitable preshaped mould at room temperature without the application of pressure. The purpose of the casting vehicle is to give the dry hard metal carbides sufficient fluidity to permit their pouring without heating. The casting vehicle is a mixture of polymerisable and non-polymerisable plastics. Removal of the casting vehicle is then effected by heating, whereby the non-polymerisable fraction is evaporated and expelled from the cast article at about 150° C. This renders the article sufficiently porous so that the polymerisable fraction can be decomposed and expelled at higher temperature without cracking the article.

● *PROBLEMS OF HEAT EXCHANGE*

Ever since the presence of a stagnant boundary layer or film on heat exchanging surfaces has been recognised as being detrimental to heat transfer by convection, attempts have been made to combat this adverse factor. In fact, the patent literature abounds with proposals either to remove the stagnant film or to minimise its effects by some special means. Many of these proposals are difficult, if not impossible, of realisation in practice, while others, as for example, the employment of scrapers to remove the film bodily, can only be used in very special cases. From the theoretical viewpoint, the presence of small surface irregularities or projections to break up the film and to produce turbulence has much to commend itself. Unfortunately, such surface irregularities, which may have the form of small surface extensions, also serve as fairly efficient collectors for foreign particles such as may be contained in the heat exchanging fluid passing over the surface. This is, of course, the main reason why, in the case of economisers and air preheaters, the use of finely grooved surfaces has not brought about the expected improvements in the heat transfer rate. A recent proposal made at an international congress of heating experts to cover the heat exchanging surface with a network of fine wire cannot, therefore, be expected to yield the improvements in practice which laboratory experiments appear to indicate.

● *HOT FORGING PRE-ALLOYED METAL POWDERS*

The recent development of pre-alloyed powders, each particle of which in reality is a tiny ingot, has enabled the powder metallurgist to design methods of fabrication directed towards the manufacture of high-strength, high-density, heat-treatable objects from metal powders. With the availability of pre-alloyed powders, the problems of the powder metallurgist are considerably simplified and resolve themselves into the design of a method for the elimination of the voids within the porous pre-form. Two general principles for obtaining completely dense parts have

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been recently developed and rely respectively on the elimination of porosity by pressure and plastic deformation, or by filling the voids with a separate alloy composition of lower melting point. The former process is known as hot coining and consists of four basic steps, namely, briquetting, heating, coining and finishing. Several alloys, both ferrous and non-ferrous, have been subjected to hot coining and, in all cases investigated to date, have exhibited physical properties and response to heat treatment either identical or superior to the same material fabricated by conventional forging practice. Analysis of the work conducted on the hot coining process to date definitely indicates that this technique can and probably will, within the next few years, begin to compete commercially in the fabrication of small forged parts. It may be readily seen that several of the normal forging steps such as upsetting and forming operations are by-passed through the use of metal powders. Some preliminary cost estimates of complex parts produced by this method have shown that cost savings up to 25 per cent may be realised when this process is put into commercial use.

● *RELEASE TRIGGER FOR HIGH-TEMPERATURE EXTENSOMETER*

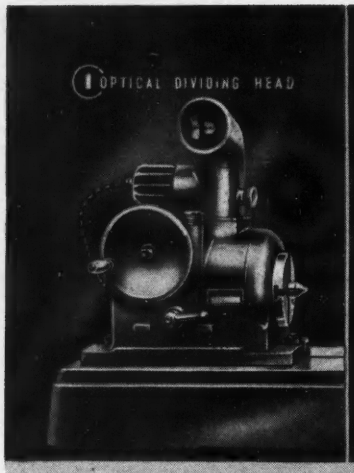
In measuring the degree of elongation with extensometers, high-temperature testing is difficult and inaccurate because the mechanism must be disconnected before the rupture point is reached. Also, insulation is necessary in order to protect the mechanism from the intense heat of the test specimen. It is claimed that with a novel type of extensometer, these difficulties are eliminated because the unit releases itself automatically from the test specimen before the breaking point is reached. The new unit consists of two rigid arms which are attached to the test specimen through a clip arm. The free ends of the rigid arms are joined by a flexible plate which carries strain gauges for measuring the deflection suffered by the specimen. A yoke and trigger mechanism is mounted on the clip arms to hold the extensometer in contact with the specimen and release it from the specimen when the desired deflection is reached. By varying the length of the trigger pin, the extensometer may be adjusted to release from the specimen after any desired deflection. The advantage of the quick-release mechanism enables the completion of the test before the specimen cools.

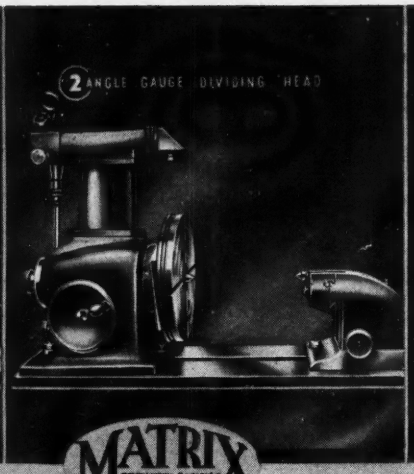
● *POST-ARC CURRENT RESEARCH*

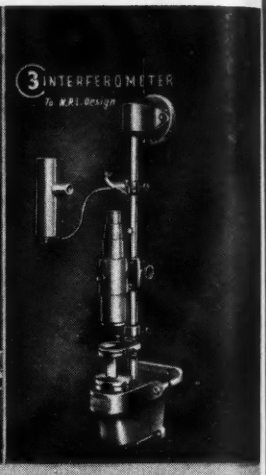
An interesting recent investigation is concerned with the phenomenon of the post-arc current, which, in an alternating current switch, is the current which keeps on flowing after the wave of the main current has passed through zero. If the main current is definitely interrupted, the post-arc current will fade out, but if re-ignition of the arc can occur, then the post-arc current actually initiates ignition. The occurrence of post-arc current in rectifiers has long been known and measured. There exist, however, considerable differences between the post-arc current in rectifiers and in oil or air switches, especially if the switches are provided with special means for de-ionisation of the arc path. The existence of the post-arc current is due to the thermionisation of the arc path which ionisation is responsible for the flow of current. It is quite obvious that the degree of thermionisation produced must be such that the resultant current flow produces the arc output required to cover the heat dissipation and to produce the appropriate degree of ionisation. As the current decreases, the temperature and the degree of ionisation will adapt themselves to the decreasing current, but there will be a certain time lag so that a certain amount of residual ionisation is present when the current passes through zero; and it is this residuum of charges which, when the field of the recurring voltage returns it to the contacts, produces the post-arc current. The post-arc current therefore provides a measure of the arc conditions prevailing during the passage of the current and the degree of de-ionisation produced by the flow of quenching fluid through the arc path.

● *OPTICAL LEVEL MEASURING DEVICE*

A newly developed optical level for measuring flatness, straightness and parallelism reads deviations from the horizontal of 0·00012 in. per foot of length, or 0·00001 in. per inch of length. It is claimed that this accuracy makes it possible to check the flatness of surface plates and machine tool beds, the straightness of cylindrical rolls, and the parallelism of V-ways or flats to values with the closest working tolerances. Critical measuring and levelling operations can be performed, and there is claimed to be no limit to the length of work that can be checked. By moving the level along a surface 7 in. at a time—which is the length of the instrument—or in shorter increments, and by taking a series of readings, the entire length of the surface can be checked and plotted on graph paper. Applications of the device include operations such as the inspection of flatness conditions of machine beds, surface plates, ground shafts, paper and dryer rolls, jigs, fixtures, airframes, lapping plates, etc. The optical system of the device consists of three bubble phials and two prisms so arranged that twice the usual accuracy of level reading is obtained. The amount and magnitude of deviation from the true horizontal in the work piece under examination are measured by means of a large-diameter graduated micrometer thimble and barrel. Half images of opposite ends of the air bubble are seen in the master phial. When these images form a perfect semi-circle, the true horizontal has been established. Separate images indicate deviation from the horizontal.







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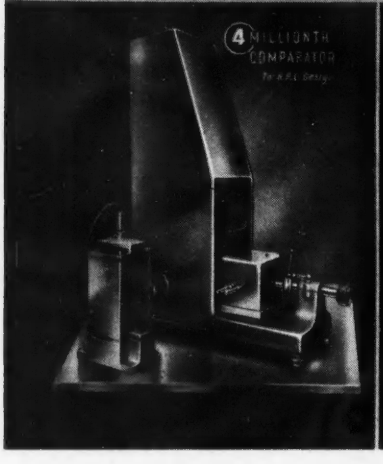

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THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIII. No. 12. DECEMBER, 1952

The Technology of Automatic Welding in the Soviet Union

RECENT ADVANCES

By J. MANNIN.

This month the author continues his survey of the techniques of automatic arc welding under granulated flux, as developed and practised in the Soviet Union. Improvements achieved since the consolidation of the basic procedures around 1947 *are classified and discussed.*

The development of automatic welding in the Soviet Union was greatly influenced by the war. The technological foundations of the process were established in the decade preceding a decree of the Central Government in December, 1940, which ordered the industrial application of the new technique. The Ukrainian Institute of Electric Welding, which was mainly responsible for its development, was evacuated into the Ural area very soon after the German advance into Russian territory. The evacuation did not interrupt the activities of the Institute, but, in the words of its own report, it " aroused the workers of the Institute to search for simpler and more reliable technological processes of welding, types of electrode wire, fluxes, electrical supply equipment, welding heads and welding installations."

The stress of war urged the introduction of welding heads with a constant rate of feed of electrode wire. This step proved to be of decisive importance. Automatic welding became one of the leading production methods in the manufacture of war equipment. The technique of welding special steels used in military equipment and the technique of making reliable, faultless joints between rough machined edges with large and varying clearances were discovered. Fluxes made from slags of blast furnaces working with charcoal were produced in one of the metallurgical combines of the Urals.

War conditions were especially conducive to a full realisation of the advantages of automatic welding, and many of the difficulties which face the much more varied requirements of peacetime production did not present themselves in the manufacture of weapons and short-lived equipment.

After the end of the war, Soviet welding research establishments were faced with the task of providing equipment and developing the manufacture of welding materials suitable for the steels and components which form the bulk of welding applications in peacetime. The first task was the technology of welding low carbon steel of medium thickness ($\frac{1}{4}$ in.-1 in.). Improvements in automatic welding apparatus led to a number of standard designs, and it was soon found that the unfused flux of the war years had to be replaced by fused fluxes which could be manufactured by the glass industry. This task appears to have been accomplished with very little delay and within two years after the end of the war, in many establishments manufacturing rolling stock, boilers, vessels and engineering structures, automatic welding was already widely used and occasionally grew into a principal production process. This phase is characterised by a consolidation of welding technology at the level described in the last contribution to this series. In June 1947 this evolution was crowned by a decree which incorporated, in quantitative terms, the achievements of automatic welding into the expansion plans of the mechanical and building construction industries. These industries are administered by no fewer than eighteen ministries concerned with transport machinery, shipbuilding, chemistry, metallurgy, building construction and others.

In this context we are concerned with the technical aspects of development and shall leave quantitative statistics for a later contribution. We should realise, however, that in the years which followed the directives of June, 1947, the bulk of automatic welding applications increased very substantially, and the introduction of standard techniques into new industries and new manufacturing organisations formed the main activity of the establishments concerned with welding equipment and welding development. In this pursuit, problems were discovered and difficulties revealed leading to further advances which are about to be discussed. These advances and their study and evaluation fill the pages of the trade press and occupy the best minds of the profession. However, in the nature of things, they remain on the fringes of the welding industry and it is not always easy to know which of the new methods reported, results achieved and discoveries made, are the product of the personal enthusiasm of one or more technicians and are fated to remain exhibits in the museum of historical curiosities, and which have the germs of further development into major industrial facts. In the following we shall concentrate on matters of technical interest, especially if this interest has a validity outside the special conditions of Soviet industry, leaving the future to decide the importance of the novelties discussed.

The subdivision into periods is artificial, and some of the improvements reported as recent advances have, in conception or even in some stage of execution, originated in an earlier period.

Classifications of the progress of any technical science can be performed in several dimensions representing different aspects. One point of view may be knowledge gained, in which a technical improvement is rooted ; it may be the appearance of new mechanisms, devices or manufacturing processes ; it may be the ability to perform new classes of operations ; and finally, it may be the manufacture of new products.

We extend to all readers our best wishes for a Happy Xmas and a Prosperous New Year

The most suitable system of classification has some relation to the structure of an industry. Under the "classical" conditions of private industry, technical advances are mainly materialised and symbolised by the appearance of new equipment or materials which constitute saleable goods. The whole system of protection (patents) and rewards is organised to encourage this emphasis.

A different approach which proceeds from the purpose of the equipment is to-day just as common in Western countries. Certainly, we are inclined to think that, in Russia, development is directed not towards the production of, say, a new welding head or welding flux preceded by market research concerning their field of application and followed by the despatch of an army of salesmen determined to saturate the potential market. We rather imagine that fresh developments are usually the result of purposeful effort directed towards well defined aims, such as the performance of welding operations not hitherto possible. On the whole, this tendency is strongly in evidence. Nevertheless, it is interesting to observe that in the reality of industrial life the principle of promoting an idea embodied in a piece of apparatus, a brand of material, or a manufacturing process is very much alive in Russia, and it would seem nowhere more so than in welding technology. A device or method originally created to solve a certain problem will acquire a life of its own and spread over a wider field if it is a sound creation. Soviet experience shows that it is a fertile principle even when the sales urge is absent. The creation itself becomes associated with the personality of an individual or an institution and we witness a lively exchange of opinions. It must be said that in the welding world there is, on the technical level, little evidence of the shadow of sanction by the State so prominent in struggles of views on more fundamental conceptions of doctrine and science. Perhaps we may assume that the welding profession has been spared the rod because of its unquestioned success in furthering engineering improvement and manufacturing productivity.

In the survey of recent advances in automatic arc welding the first classification subdivides development by its aims. These belong to one of the following groups :

(1) Improvement of the physical or chemical qualities of the welded joint.
(2) Improvement of economy in welding through raising the productivity of labour or saving of power or materials.
(3) Extension of automatic welding to joints not previously amenable to this method on account of their shape or position (very thick or very thin gauge ; vertical and overhead joints ; space curvature of joint ; short length of joint).
(4) Extension of automatic welding to unprepared sites or arduous working conditions.
(5) Introduction of automatic welding into specialised operations (plug welding, attachment of studs, sockets and bosses).
(6) Extension of automatic welding to the joining of materials not previously arc welded under flux.

The second classification of progress centres around equipment or materials newly developed :

(a) Fluxes of new or modified composition have appeared and their effect on various welding operations and materials tested.
(b) A hotly contested development has been the evolution of steel specifications specially suitable for automatic welding.

Four devices and methods are the principal novelties in the period under review and are generally considered as established improvements already active in industrial applications :

(c) Semi-automatic welding method by means of a "hose apparatus" which ensures an automatic feeding of thin electrode wire through a flexible hose, but leaves the guidance of the welding arc entirely to manual control and dispenses with the reclaiming of unused flux.
(d) Three-phase welding under flux.
(e) The twin arc process based on the use of two differently inclined electrodes electrically connected in parallel and spaced along the seam.
(f) Die forming of the welding seam by water-cooled copper dies which follow the welding arc.

Further novel methods have been proposed and some tested, with uncertain results so far.

(g) The use of liquid filler metal in addition to the melting of the electrode wire.
(h) Arc welding under two layers of different fluxes.
(i) Welding with two arcs in series spaced along the seam.
(j) The use of non-melting electrodes (tungsten, carbon) under flux for non-ferrous metals.
(k) Co-ordinated individual control of arc voltage and arc current.

A number of new devices and methods are improvements of detail originally arising from specific applications. In the pattern of the industrial welding economy, many small improvements and specialised installations have acquired far greater importance than the more fundamental novelties enumerated above.

In the numerous applications of welding, some devices, fixtures and equipment have often been milestones of progress which most engineers will judge as conventional solutions to straightforward engineering problems. Details of such solutions are so strongly influenced by the industrial environment represented by available standard equipment and materials, that their thorough discussion cannot enrich our technical knowledge. We refer here to various fixtures and fittings for the precise guidance of the welding arc, universal and special holding and clamping fixtures for components, elaborate and often very ingenious supporting and handling structures in the erection of engineering works (including large magnetic tables for thin-gauge work) ; and last, but not least, the development of electrical supply equipment. To illustrate the last point, eighteen months ago, the absence of suitable welding generators for field work delivering as little as 1,000 amperes and driven by an internal combustion engine was lamented. The spread of high-powered automatic welding into undertakings such as long-distance pipe lines and bridge building is likely to make additional demands on equipment under special conditions.

Finally, recent developments can be related to the products into which they enter. Some of the most spectacular novelties, from this point of view are large-diameter welded pipes, spirally welded pipes, cylindrical and spherical reservoirs, all-welded bridges and the shell of a blast furnace, regarded by Soviet technicians as a crowning achievement.

These classifications help to appreciate the position of each novelty in automatic welding in relation to the whole branch of welding. The discussion which follows is not a comprehensive treatise. We shall select those points where valuable and instructive information is available.

The question whether welding methods should be adapted to the steel in use or the steel adapted to the welding procedure of the highest productivity involves major industrial decisions and is, not unnaturally, the subject of much controversy and conflicting interests. Rational decisions are made more difficult by the absence of a simple and universal criterion of weldability, a problem which has baffled Soviet engineers as much as any. The "welding side" won a significant victory by the end of 1950. A quotation will illustrate that in the struggle of opinions, something suspiciously similar to

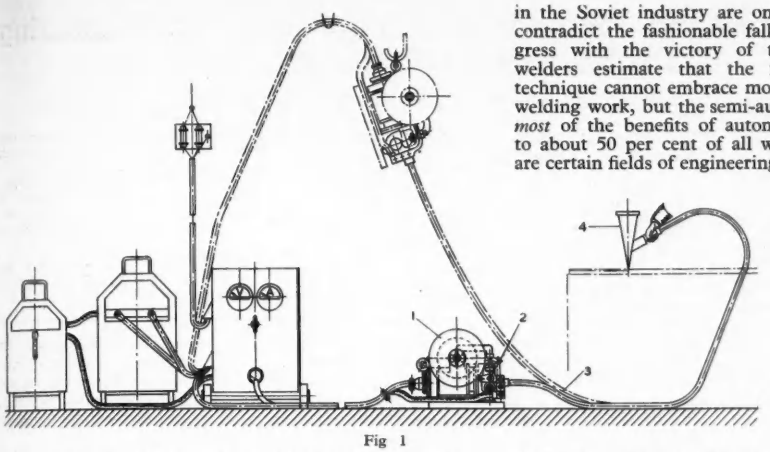


Fig 1

vested interests seems to have been rearing its ugly head.

" It must be said that almost four years ago, when our Institute, for the first time in the Soviet Union, came out with the proposal of selecting an improved steel for welded structures, this proposal was met with hostility by some of the workers of the Ministry of Metallurgical Industry. Their views were echoed by certain welders. They held that the Institute was crying out for an improved steel because it was unable to evolve a welding technique which would ensure a good quality of the structure irrespective of the quality of the steel. What was needed, it was said, was to adapt welding to the steel and not the steel to welding."

" Times have changed now. The metallurgists have understood that good weldability is one of the fundamental requirements to be met by a steel."

It is well known that a zone in the parent metal between the welding seam proper, the material of which takes part in the melting and solidification cycle, and the untouched metal is subject to reduced plasticity (as revealed by elongation and other tests). An analogy with the phenomenon of ageing is responsible for calling this zone the zone of ageing. In the welding of *rimmed* steel the zone of ageing is subject to a large increase in brittleness. The situation is decisively improved by the use of *killed* steel. Altogether, for welded components of structures which have to meet the highest requirements of reliability, including resistance to low temperatures, the following demands must be made on the steel :

(1) The carbon content must not exceed 0·20 per cent ; silicon—0·25 per cent ; sulphur—0·050 per cent, and phosphorus—0·045 per cent.
(2) The steel must be killed by thorough oxidation with silicon and aluminium.
(3) The steel must have a homogeneous structure, small grain size and a uniform distribution of sulphur and phosphorus.
(4) The thermal cycle in the rolling process must leave no traces of overheating in the product.
(5) The steel must not have a strong tendency for ageing.

Amongst all recent innovations, some Soviet welders attach the greatest importance to the semi-automatic welding process by means of the hose apparatus. To the author it has a special significance. If the elimination of the human element, symbolised by the word " automatisation," is regarded as the scale of progress, then the introduction of semi-automatic welding after the fully automatic process can be looked upon as a retrograde step. However, I believe that the development of semi-automatic welding and its great expansion in the Soviet industry are only another illustration to contradict the fashionable fallacy which identifies progress with the victory of the automaton. Russian welders estimate that the fully automatic welding technique cannot embrace more than 20 per cent of all welding work, but the semi-automatic system can bring *most* of the benefits of automatic welding under flux to about 50 per cent of all welding operations. There are certain fields of engineering where elimination of the human element from the process benefits the process ; there are others where the elimination of work from the human element benefits the human element, but, in manufacturing industry, a large percentage of operations does not belong to either class. Technically, the appearance of the hose apparatus is the direct result of the discoveries about the effects of automatic arc welding with thin electrodes (1·2 to 3 mm) operating at high current densities.

(a) A considerable variation of the proportion of parent metal in the welded seam is possible. The depth of penetration of the arc for the same current increases with current density. Simultaneously, the fusion factor of the electrode wire (gr/Ah) increases by a multiple of two or three. The combined result is that much thicker gauges can be welded with a single pass and that the proportion of parent metal is reduced to 40 per cent. This enables wider limits of carbon and sulphur content to be tolerated in the parent metal.

(b) The increased current density improves the stability of the arc down to currents of 140 A. Semi-automatic welding can be applied to thin gauges and fillet joints of small section.

(c) Other things being equal, thin wire reduces the consumption of electric energy by 25 per cent compared with the consumption necessary with a wire of 5 mm. The weight of electrode wire per unit length of seam is reduced by 15 per cent.

(d) On the whole, the influence of thin wire on the metallurgical processes taking place during the welding cycle is favourable. Phosphorus, however, is transferred from the flux into the metal and some enrichment in silicon and manganese also takes place. These must be carefully watched and a suitable flux chosen.

(e) Porosity and the formation of cracks in the hot state are much less pronounced when a thin electrode wire is used. In practice, more finely granulated flux is used in semi-automatic welding, which also contributes to a lesser tendency for the formation of cracks.

(f) The more concentrated application of heat, owing to the higher current density, reduces the extent of the zone in the parent metal subject to grain growth.

(g) Electrodes of small diameter can be used in a twin arc arrangement in place of a single electrode of thick wire. The ease with which the arc is struck and maintained renders more reliable automatic devices and leads to high mechanical qualities of the joint in spite of a high speed of welding. Electric power equipment employed for manual welding can be more conveniently incorporated in an installation for semi-automatic welding than in a fully automatic installation with thick electrode wire.

Based on these properties of the thin electrode arc under flux, the " hose apparatus " was brought out by the Ukrainian Institute for Electric Welding after rejection of several unsuccessful attempts to accomplish a partial mechanisation of the welding operation.

(*Continued on page* 438)

GERMANY

Test Procedures and Methods for Eliminating the Measuring Errors of Thermometers

By F. LIENEWEG. (From *Feinwerktechnik*, Vol. 56, No. 11, November, 1952, pp. 325-332, 14 illustrations.)

THE reliability of temperature measurements depends not only on the quality of the thermometer but also on the correctness of the method of taking measurements. In setting up the measuring apparatus, it is necessary, therefore, to consider whether the requirements for which it is to be used can be satisfactorily fulfilled or whether they imply an abnormally high degree of accuracy in the test apparatus and test procedure.

A few remarks, therefore, on the accuracy of electrical instruments and thermometers should be useful. Electrical measuring instruments are divided into a number of classes corresponding to their accuracy as a percentage of the scale length. Precision instruments are designated Class 0·1 or 0·5 instruments, and ordinary apparatus is known as Class 1, 1·5, 2 or 2·5 equipment, according to their design. The error of thermocouples employing base metals is normally in the 0·3-0·4 mV range, whereas for PtRh-Pt thermocouples it is situated around 0·05 mV. Thermocouples with only half this error can be made for special requirements. Resistance thermometers have an error limit of ±0·5-0·75 per cent of the indicated value, and at room temperature the error is 0·3-0·5° C with resistance wires of platinum or nickel.

These figures show that a careful choice of the type of instrument to be used is essential in order to obtain suitable measurement accuracy. Table I gives examples of the degree of accuracy achievable with various types of measuring instruments and thermocouples. The values given do not include allowances for temperature influences at the reference position, deviations from required resistivity values or temperature rises in the indicating instrument. The mean error is calculated as the root of the sum of the individual errors squared, according to the error distribution law. It is useless to require accuracies to less than ±5° C for the range of temperatures considered. Furthermore, the accuracy of a thermocouple becomes a secondary consideration when it is compared with that of other instruments also used in the tests, unless additional influences, such as ageing, give rise to increased measuring errors.

It is also necessary to verify that the high-temperature source itself complies with the requirements. Thus, there should be no large temperature variations at various points in a furnace, and constancy of temperature should be maintained by the control devices with the accuracy required for the measurement. The temperature-sensitive element should be correctly mounted in the furnace, since considerable errors may occur through heat dissipation and radiation, or owing to the pressure of vapours (in the case of optical pyrometers.)

Thus, measuring errors can be traced to the following factors :—(1) the temperature-measuring device and its components, (2) the location of the measuring position in the body to be measured and its surrounding medium, and (3) the mounting arrangement and input and output leads.

EQUIPMENT FOR A THERMOMETER TEST ROOM

When a high accuracy is required in temperature measurements, it is essential to have the measuring instruments periodically checked and maintained by technicians specialised in this subject, and disposing of the appropriate testing equipment for field tests and laboratory work.

Measuring instruments: For laboratory tests of instruments, high quality standards are required, such as precision type mercury thermometers for temperatures up to about 600° C. These should be periodically tested and calibrated, if possible, at a recognised Physical Laboratory. A large number of simple precision thermometers, as well as accurate resistance thermometers and thermocouples, are also needed. In measurements with liquid thermometers, the filament correction should not be omitted.

TABLE I. OVERALL ERROR OF VARIOUS MEASURING INSTRUMENTS AND THERMOCOUPLES.

Type of instrument	Range °C	Error limits ±	Overall limits with PtRh–Pt thermocouple having an error limit of ±5° C	±3° C
Precision	0–1600	0·5% = 8° C	±9·5° C	±7·3° C
Ordinary	0–1600	1·5% = 24° C	±24·5° C	±24·2° C
Compensated	400–1600	0·4% = 4·8° C	±7° C	±5·7° C

The equipment for a thermometer test room also includes precision type indicating instruments for the testing of resistance thermometers and thermocouples, that is, for instance, light-spot galvanometers with a minimum sensitivity of 1 mV, and pointer type moving coil instruments for values between 20 and 60 mV. Moreover, to obtain small test voltages, simple voltage sources, voltage dividers and compensators are required for many applications, as well as rotary or decade resistances for values between 0·01 and 1000 ohms. A good measuring bridge is needed, which can give an accuracy of 0·01 to 0·1 ohm in measuring resistances of 100 to 300 ohms. In addition, there should be available various null type galvanometer sets, voltmeters and ammeters for voltage and current indication, as well as insulation testing equipment for tests on leads and wiring.

Test apparatus: It is also necessary to have test rigs and apparatus for the production of constant and uniform temperatures. For thermocouples, the safest arrangement for obtaining a zero reference temperature is a thermos flask filled with a mixture of ice and water. A constant temperature of 100° C is obtainable with an arrangement in which the thermometer unit is in contact with the vapour of boiling water. For very accurate measurements, the influence of barometric pressure on the boiling point should be taken into account, and care should also be taken to avoid any errors due to the protruding part of the thermometer element.

For higher temperatures, tests at fixed reference temperatures are also possible. Thermocouples, for instance, can be tested in a very simple manner by the gold-wire method. The free ends of the thermocouple are connected together with a thin gold wire. The furnace temperature is raised until the electrical connection is broken at the melting point of gold ; the maximum voltage reading thus obtained corresponds to a temperature of 1063° C. Generally, however, thermometers are calibrated at higher temperatures by comparative tests with standard elements. Both thermometers are put into a liquid bath, which is electrically heated and stirred by a mechanically-driven helical type stirrer situated at the centre. With this arrangement, temperatures between —20 and +350° C can be obtained, using freezing mixtures or suitable oils. For tests up to 750° C, electrically-heated metal blocks are used. The block is thermally isolated from the exterior and the thermometers are placed as close as possible against the walls and situated in deep recesses in the block.

Thermocouples and their connections, and the measuring resistances of electrical thermometers, are

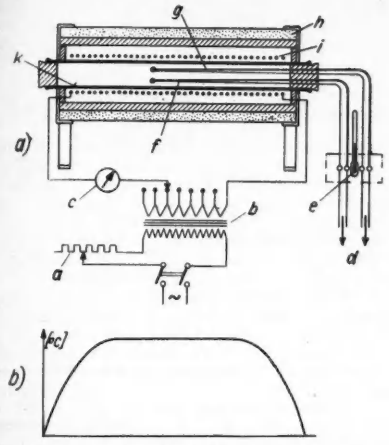


Fig. 1. **Electrically heated tubular furnace for the testing of thermometers.**

(a) Schematic drawing : a = regulating resistance, b = adjustable transformer, c = ammeter, d = leads to voltage indicating instruments, e = reference position, f = thermocouple under investigation, g = standard thermocouple, h = heat insulation, i = heating coil, k = induction heating tube.
(b) Temperature distribution along the heater tube.

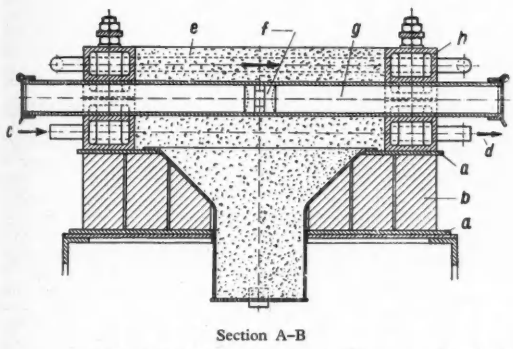


Fig. 2. **Carbon tube furnace for tests of radiation pyrometers.**

a = insulating plates, b = insulating stones, c = cooling water inlet, d = cooling water outlet, e = carbon-powder, f = carbon block, g = carbon tube, h = cooling webs, i = current supply.

conveniently tested in an electric furnace as shown in Fig. 1. To obtain a uniform temperature distribution, it is an advantage to insert a second tube into the furnace, and to introduce the test specimen and the calibrated standard through this tube, which is then hermetically closed at both ends. These furnaces are used with heating coils of nickel-chromium wire up to 900° C, platinum-foil type coils up to 1300° C, and molybdenum coils up to 1500° C. In molybdenum furnaces, however, the coil must be situated in an inert-gas atmosphere to avoid oxidation of the wire.

In principle, the tests should be carried out with increasing and decreasing temperatures. The resistances and leads used in conjunction with the measuring instrument should also be taken into account.

For the testing of total-radiation pyrometers, carbon-tube furnaces are employed (see Fig. 2). The carbon tube g is heated with about 15 kW through a transformer. A carbon block f situated in the middle of the tube is viewed with the pyrometer to be investigated and an incandescent-filament type pyrometer used for comparative measurements.

If incandescent-filament type pyrometers are to be

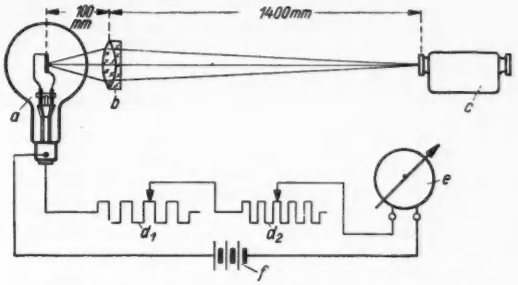
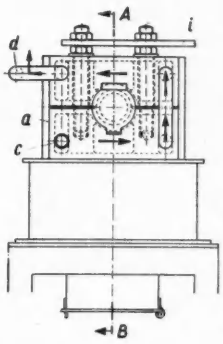


Fig. 3. **Band-spectrum lamp testing arrangement for radiation pyrometers.**

a = band-spectrum lamp, b = lens system, c = incandescent filament pyrometer, d_1, d_2 = regulating resistances, e = galvanometer, f = battery.

tested, a band-spectrum lamp and testing arrangement are required (see Fig. 3). These lamps do not give a black-body radiation but they enable remarkably good calibrations to be obtained. The band-spectrum lamp a is raised to any operating temperature, which is first determined with a calibrated standard filament-type pyrometer c and then measured, for comparative values, with the pyrometer to be tested. A frequently used alternative procedure is to determine the relation between electric current and temperature of the band-spectrum lamp, for the effective wavelength of the standard pyrometer, and the current indication is then used as a measure of the equivalent temperature. In such tests, the pyrometer being investigated must have the same effective wavelength as the standard unit, and the same lens system b must be used in all measurements. With great care, an accuracy of $\pm 5°$ C at 1400° C can be obtained, and $\pm 10°$ C at higher temperatures.



Total radiation pyrometers can be tested in a simple manner with any radiation furnace, even when the latter cannot be regarded as a true black-body radiator. Comparative measurements are then made with a calibrated pyrometer of the same type, which is used only for this purpose. Incandescent-filament pyrometers can also be tested in this same manner, with standard pyrometers of the same design. The indications of a colour pyrometer can also be compared with those obtained with a thermocouple immersed in a melt, provided that the melt surface, like that of iron melt, is free from slag and can be regarded as a grey-body radiator.

TESTING OF THERMOMETERS

Resistance thermometers: The testing of electrical thermometers requires extensive knowledge of their measuring properties. With resistance thermometers, the constancy of the measuring resistances is generally very satisfactory, particularly for platinum. If, however, there are doubts about their accuracy, comparative checks are necessary with standard resistance thermometers or glass thermometers previously tested. Besides determining the limits of the error due to the measuring resistance itself, for thermometers enclosed in long

protective cylinders the value of the internal conduction resistance should be considered, that is, the resistance of the leads between the measuring resistance and the outside terminals, which may otherwise give rise to a constant error.

The indicating instruments can also be checked by inserting in the circuit the required value for the compensating resistance for the leads between the thermometer and the indicating instrument considered. A different standard resistance is employed for each range of the instrument. The tests should be made at a temperature of 20-22° C, this being the calibration temperature of such instruments.

Thermocouples: As the properties of thermocouple wires alter considerably with time when thermocouples are used for temperature measurements in hardening baths, owing to recrystallisation and other ageing phenomena, the wires should be replaced periodically. In carrying out tests, thermocouples should first be investigated as regards their output voltage. For this purpose, null-balance circuits are generally employed, in order to avoid introducing undesirable errors due to the resistance of the thermocouple wires and leads. For tests of this kind, as well as for others that will be described later, there are two different procedures, which are based on the use of a voltage indicator or a compensator unit, respectively. Descriptions will be given in the following of these two methods and their corresponding circuit arrangements.

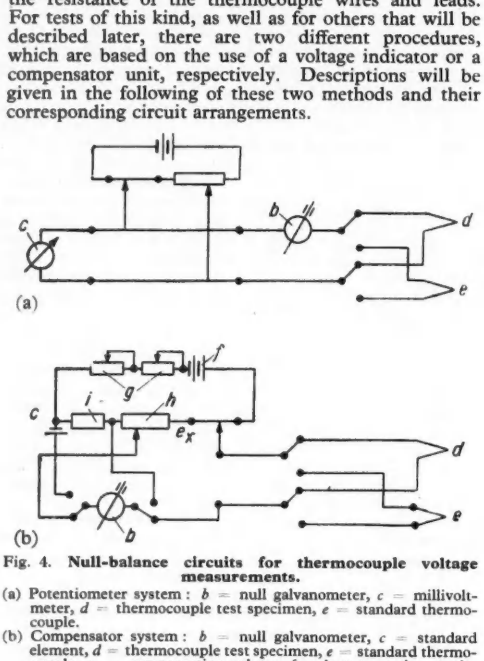


Fig. 4. Null-balance circuits for thermocouple voltage measurements.

(a) Potentiometer system : b = null galvanometer, c = millivoltmeter, d = thermocouple test specimen, e = standard thermocouple.

(b) Compensator system : b = null galvanometer, c = standard element, d = thermocouple test specimen, e = standard thermocouple, e_x = compensating voltage, f = battery, g, h = resistances, i = fixed resistance.

For tests of the output voltage of thermocouples, the specimen to be investigated is placed in a furnace together with a calibrated standard thermocouple, and the voltage is measured with the aid of one of the circuits in Fig. 4. In these tests, the temperature at the reference position should be maintained at a constant value. When using the circuit arrangement of Fig. 4a, the potentiometer is adjusted until the null galvanometer b shows zero current. Then, regardless of the resistance of the thermocouple, the voltage across the millivoltmeter c will be the output voltage of the thermocouple at the furnace temperature. Switching over to the standard thermocouple, the millivoltmeter indication gives the true thermoelectric voltage for the combination of materials considered, and the true corresponding temperature can be determined. The difference in the results gives the measuring error. The measurement accuracy depends on the classification accuracy of the

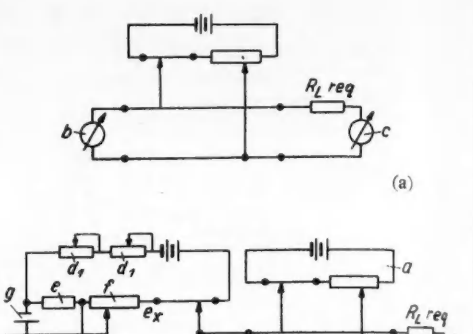


Fig. 5. Circuit for tests of indicating instruments.

(a) Potentiometer system : b = millivoltmeter, c = instrument being tested, $R_{L\,req}$ = required value for leads resistance.

(b) Compensator system : a = voltmeter, b = null galvanometer, c = instrument being tested, d_1, d_2 = circuit resistances, e = fixed resistance, f = decade resistance, g = standard element, e_x = compensating voltage, $R_{L\,req}$ = required value for leads resistance.

millivoltmeter, which is 0·2 to 0·5 per cent of the scale length for " precision " class instruments.

In the circuit arrangement of Fig. 4b with a compensator unit, the thermoelectric voltage is compensated by a voltage e_x which is read off the compensator unit. Before compensation, the voltage drop on the measuring potentiometers is adjusted to the required value with the aid of a standard element in the usual manner. The measurement accuracy depends mainly on the reliability of the standard element. With good compensator units, a voltage reading accuracy of 0·3 per cent can be obtained.

Besides the thermocouple voltage, it is necessary to check the accuracy of the measuring instruments, using one of the circuits of Fig. 5. By means of a potentiometer, various voltages are applied to the instrument being tested. The series resistance in the circuit must have the required value representing the leads resistance, to which the instrument is adjusted, for instance 20 ohms. The voltage applied to the voltmeter under investigation can be determined from the indication of the compensator or the reference millivoltmeter and this is compared with the thermocouple voltage for the type of thermocouple considered.

In testing indicating instruments, the errors due to frictional effects should also be determined. They should be within the accuracy limits of the corresponding classification number, and for factory type instruments of class 1·5 they should not exceed this value as a percentage error. A check of indicated values before and after a gentle tapping of the instrument should be made, and the frictional errors thus made apparent should be recorded.

Radiation pyrometers: In the testing of radiation pyrometers, due care should be taken to distinguish between the error of the pyrometer itself and those of the indicating instrument and the test arrangement. In the case of incandescent-filament type pyrometers, if the indicating instruments have a mechanically suppressed zero position, it is a primary necessity to check the indicated values of current frequently, since a zero-point check cannot be carried out.

The measuring error of total radiation pyrometers is between 15° and 25° C, according to the temperature level. If, however, the calibration is obtained by comparison with thermocouples or by means of baths of known temperature, it is possible to reduce the error to even lower limits.

(To be continued)

Indium Alloys for Commercial Uses

By R. I. JAFFEE and S. M. WEISS. (From *Materials and Methods*, Vol. 36, No. 3, September 1952, pp. 113-115, 7 illustrations.)

The special properties gained by alloying indium with lead, tin, cadmium or bismuth can be put to good use in bearings, solders and glass sealing alloys.

INDIUM is a silvery white, extremely soft metal. It is the softest metal that is stable in air. It is highly plastic, and deforms under compression almost infinitely. Indium does not work-harden, and actually softens during rolling. This is because the recrystallisation point is well below room temperature.

The commercial value of indium lies in its alloys with the closely related metals lead, tin, cadmium and bismuth. Indium-lead alloys have higher melting points than any of the others. Thus, in applications such as solder, they would have a clear advantage in useful temperature range. Also, the indium-lead alloys are the hardest and strongest over most of the range of alloy content.

In the indium-rich alloy region, bismuth is the most effective hardener, followed by cadmium, and then by lead. These effects were found in the indium solid solution region. Tin, which has the least room-temperature solubility in indium, has the mildest strengthening and hardening effects.

Indium in solid solution is most effective in hardening tin. It is somewhat less effective in hardening lead, but since the solubility of indium in lead is so much greater, the maximum hardness and strength attained in the lead-indium solid solution are somewhat greater. Indium is practically insoluble in cadmium or bismuth, and it has no hardening effect on either of these metals.

BEARINGS

The chief application of indium has been in aircraft bearings. Indium is plated and diffused on a steel-backed bearing which had previously been plated with a layer of silver and then lead. After diffusion (500 hr at 302° F), the concentration of indium at the surface is about 16 per cent. This corresponds to a solid solution alloy of indium in lead. The improved strength and hardness of the lead-indium alloy surface do not account for the desirable bearing performance obtained with this bearing. The indium is used principally to improve corrosion resistance against organic acids in lubricating oils. However, it is probably true that the enhanced mechanical properties of the indium-lead layer do not detract from the bearing properties.

Indium diffused into a steel-backed cadmium-alloy bearing improves corrosion resistance without impairing fatigue resistance. Here, after diffusion, there is about 0·4 per cent average indium content in the cadmium-alloy bearing. This amount of indium does not detract much from the strength of cadmium. Less complete diffusion would result in a major decrease in strength and, perhaps, in performance.

SOLDERS

It would be expected that, because of the major strengthening effects of indium in both lead and tin, indium would increase the strength of lead-tin soft solders. Such is not the case. Additions of 10, 25 and 50 per cent of indium to 50-50 lead-tin solder decrease, rather than increase, the shear strengths of ring-and-plug joints between mild steel members. This may be because much of the usefully high strength of 50-50 lead-tin is derived from solid-solution strengthening effects of lead and tin in each other. The presence of indium as a ternary component may reduce the mutual inter-solubility of lead and tin. However, the ternary indium-lead-tin soft solders have improved resistance to alkalies, the purpose for which they were developed.

Indium additions of 1 and 2 per cent to a lead-base 3 per cent silver soft solder increase strength markedly.

GLASS SEALING ALLOYS

A very useful present application of indium is in the form of an alloy containing about equal amounts of tin and indium. It is capable of wetting glass and of making glass-to-glass or glass-to-metal seals. The alloy is first applied to preheated glass by swabbing. Joints and seals can then be made in conventional ways.

It is interesting to compare this and other alloys of indium with lead, tin, cadmium and bismuth for their abilities to join non-metallic materials. It takes a surprisingly small concentration of indium to cause wetting of glass. All of the bismuth-indium, cadmium-indium and indium-lead which contained 5 per cent or more indium can be applied to glass and used for making joints. It takes more indium, however, to promote wetting of glass by indium-tin alloys. A 40 per cent indium alloy in tin will wet, but a 20 per cent alloy will not.

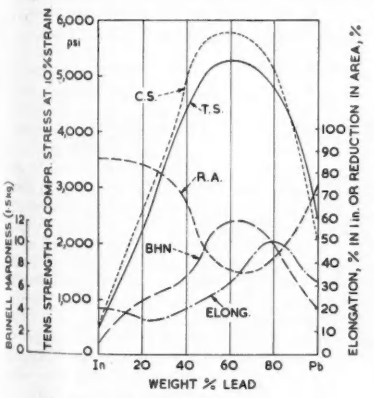


Fig. 1. **Mechanical properties of indium-lead alloys.**

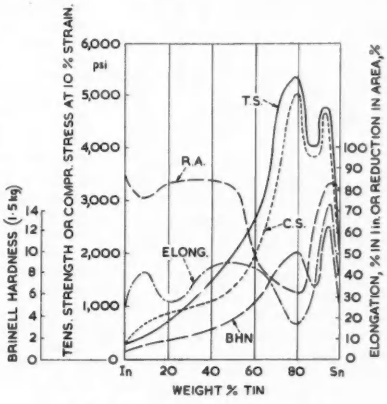


Fig. 2. **Mechanical properties of indium-tin alloys.**

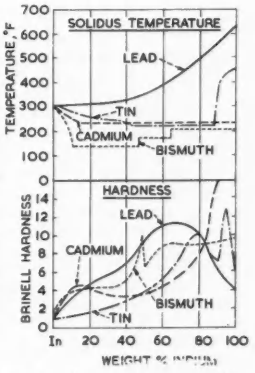


Fig. 3. **Comparison of solidus temperatures and hardness of the alloys of indium with lead, tin, cadmium, and bismuth.**

One undeniable advantage of the higher indium content glass sealing alloys over those which are lean in indium, is their ease of spreading on glass. When the indium content is low, there is only a small temperature gap, just below the liquidus temperature, where good spreadability of the molten alloy on glass is obtained. At higher concentrations, around 50 per cent or more indium considerable leeway in temperature is permissible. Shear strengths of glass-to-glass seals vary from 350 to 1000 psi.

It would appear that the indium-lead alloys, with their higher melting points, would have certain advantages as glass sealing alloys, since temperature is a critical factor in many glass-to-metal seal applications. Compared with the 50 indium-50 tin glass sealing alloy for example, a 50 lead-50 per cent indium alloy would have an advantage of about 140° F. However, the vacuum tightness of seals made with an indium-tin eutectic alloy is considerably better than that of the indium-lead alloy. Resistance to cyclic thermal stresses set up by alternately heating and cooling between 212° F and — 58° F is excellent for both types of vacuum seals.

JAPAN

The Cloud Point Test for Low-Temperature Lubricating Oils

By E. KANDA and T. HASEDA. (From *Science Reports of Tôhoku University*, Series A, Vol. 4, No. 1, February, 1952, pp. 48-52, 4 illustrations.)

THE usual method for determining the cloud point of low-temperature lubricating oils is imperfect, both from the practical and the theoretical point of view. After cooling in an alcohol/dry ice bath for a certain period of time, the sample contained in a test tube is removed for a turbidity observation. However, observation soon becomes difficult owing to frosting on the outer surface of the test tube. Furthermore, the mercury thermometer is immersed in the bottom of the test tube, with the result that the exact temperature of the sample is hardly known owing to the poor conductivity of the sample in the course of cooling or heating.

In all turbidity tests,[1] owing to the high viscosity of the oil, particular precautions are necessary to ensure that the temperature equilibrium shall be established. Even a slight difference in the thermal characteristics or in the cooling rate results in an appreciable difference in the setting in of clouding. To obtain relative values for the cloud point, it should be sufficient to test at a constant cooling rate, but the usual method is not sufficiently accurate even for this purpose.

TURBIDITY TEST METHOD BASED ON PHOTO-ELECTRIC MEASUREMENTS

A new method for cloud point determination was developed by the authors. It is based on the photo-electric measurement of the intensity of light transmitted through oil at various temperatures. A sketch of the apparatus is shown in Fig. 1.

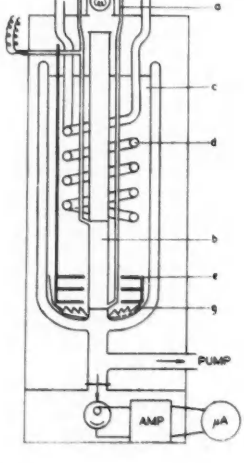


Fig. 1

The light from a standard 200-watt tungsten filament lamp *f* passes through the sample container *b* to a photo-cell, the output current of which is amplified in a suitable circuit.[2] Even slight changes in turbidity can be detected. The sample is introduced through the opening *a* into the container *b* which has a capacity of about 30 cm³ and which is protected from moisture by a calcium chloride tube. The container *b* is in an alcohol bath *c* and is surrounded by a cooling coil *d*, through which flows liquid nitrogen. The cryostat (a specially made Dewar vessel) also contains a stirrer *e*. A thermocouple at the top of the container measures the temperature, which can be controlled to within ± 0·1° C by adjusting the flow of nitrogen through the coil *d* and regulating the current of the heater *g*. At the beginning of the test, when the sample is fully transparent, the current is adjusted to 100 μA. The current falls off with increasing clouding. Turbidity is hardly observable with the naked eye until the current falls to 90 μA.

LOW-TEMPERATURE FILTRATION

Filtration at low temperature was tried for the refinement of the quality of oil, using the arrangement shown in Fig. 2. The entire section *A* is immersed in a cryostat which is kept at the required temperature during filtration. Part *b* is filled with particles of silica gel; *a* is a glass filter, and filtration is obtained by suction from *C*. Filtration was performed at —25° C and —43° C with the ordinary glass filters used for chemical analysis. The operation takes a considerable time. Further tests would be necessary to determine the optimum mesh of the glass filter and the proper amount of silica gel.

DESCRIPTION OF TESTS

Cloud point tests: Low-temperature lubricating oil made from fish oil was tested in the new apparatus. The plot of the microampere readings against temperature over the range 0° C to —25° C and back to 0° C with the usual rate of cooling gave a large hysteresis loop. By using a sufficiently slow rate of cooling to obtain perfect equilibrium, the hysteresis loop was reduced to a single curve, which showed a cloud point at 0° C with a point of inflexion at —15° C, whereas by the usual method of turbidity determination the cloud point appeared to be at about —20° C. After filtration at —25° C, the sample was tested again from 0° C to —40° C and back to zero. The resulting single-line and hysteresis-loop diagrams showed three step-like changes, which suggested the presence of three species of impurities. The sample was filtered once more at —34° C and the following test showed a practically horizontal line down to —35° C with a slight drop thereafter to 96 μA. With this sample, the cloud point, i.e., a 90 μA reading, was reached at —60° C, whereas it appeared to be at —80° C in the

diagram obtained by the usual method. From the comparative indications of the various curves, it is possible to assess the amount of clouding impurities, and this is not achievable by previous methods.

Rate of clouding: The microampere readings were also plotted against the time during which the sample was kept at each constant temperature. From the length of time during which the microampere reading decreases at each constant rate, it is possible to assess the induction period corresponding to each precipitation. The rate of clouding at each temperature was related to the viscosity at the corresponding temperature, measured by means of a specially made Ostwald type viscometer. The results obtained are given in the following table:

t °C	rate k μA/min	η poises	$k\eta$
—28	0·27	15·1	4·05
—31	0·20	21·0	4·20
—40	0·059	70·2	4·08

The table shows that the value of the product $k\eta$ is almost constant for every temperature. This fact may be related to the rate of crystallisation, which was measured for supercooled glycerol by Volmer and Marder.[3] On the basis of their data, Richards obtained a relation[4] indicating that the rate of crystallisation is inversely proportional to viscosity, in the case of glycerol. Another factor to be considered is that, generally, the scattering of light is proportional to the size and number of scattering particles. It is difficult, in the present case, to determine the relative importance of these two factors. The constancy of $k\eta$, however, seems to indicate that the rate of clouding is proportional to the reciprocal of viscosity for medium oils.

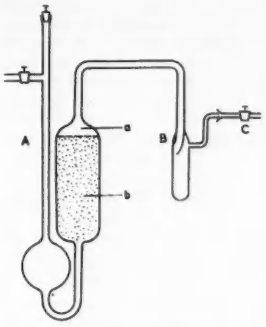


Fig. 2

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FRANCE

Electrical Analogies for Heat Transfer Problems

By L. MALAVARD and J. MIROUX. (From Proceedings of *Fourth International Congress for Industrial Heating, Paris*, 1952, Group 1-Section 13, Paper No. 82, 7 pages, 6 illustrations.)

*The study of heat transfer problems with steady-state or transient conditions can be achieved with a considerable saving in time and labour by using electrical analogies. This article describes the methods and equipment employed for this purpose at the C.N.R.S. and O.N.E.R.A. Laboratories.**

PROBLEMS WITH STATIONARY BOUNDARY CONDITIONS

Stationary boundary conditions exist when the temperatures at boundary positions (i.e., hot sources and cold sources) are maintained at constant values. Problems with conditions of this kind are solvable by two main methods, viz., the electrolytic method and the electronic network method.

In the electrolytic method, the electrolyte is placed in a basin which is similar in shape to the volume or surface under consideration. With a suitable arrangement of the electrodes, the distribution of electrical potential in the electrolyte is governed by the same equation as the thermal problem. In a direct analogy, temperature is represented by voltage and the heat flow by electric current, and there is continuous correspondence at every point between the two fields.

In the network method, a multi-mesh circuit is used to represent the thermal field conditions. The equation with partial derivatives is replaced by an equation with finite differences which refer to the nodal points, so that the measurements give representative values at individual points instead of covering a continuous field. Although the problems to which these two methods may be applied are sometimes widely different, it is frequently an advantage to make use of both methods so as to obtain complementary indications.

THE ELECTROLYTIC METHOD

The electrolytic method is particularly simple for the study of fields with a constant thermal conductivity.[7] The electrolyte with a constant resistivity is in a trough of the required shape and voltage measurements determine the equivalent temperature distribution. For three-dimensional problems, deep basins are used. For two-dimensional problems it is more convenient to have a shallow basin representing a section (between parallel planes) of the object to be investigated. In dealing with axially symmetrical problems it is preferable to use basins with a sloping bottom surface; the model thus represents a section of the object between two meridian planes forming an angle of a few degrees.

In two-dimensional cases, two analogies are possible, viz.: (a) voltage equivalent to temperature, and (b) voltage equivalent to heat flow, which is the "associated function." By using both analogies, the orthogonal network consisting of isothermals and constant heat-flow lines can be determined, with two different models for the same problem. For fields with rotational symmetry the flow lines can be determined in basis in which the depth at any point is inversely proportional to the distance to one of the edges taken as representing the axis of rotation.

The required boundary conditions not only define the thermal problem but also determine the arrangement by means of which electric current is supplied to the model. The simplest arrangement consists of two electrodes, representing the two boundary isothermals (hot source and cold source), which are directly connected to the two terminals of the current supply.

*C.N.R.S. — Council for Scientific Research, and O.N.E.R.A. Aeronautical Development and Research Board.

In simulating practical applications, the conditions at curved boundaries usually require the introduction of a "transition coefficient" α at the wall, so that at each point along the wall the temperature and its derivative in the normal direction n shall fulfil Fourier's relation

$$\lambda \, dT/dn = \alpha \, (T - \overline{T})$$

where λ = thermal conductivity and $\overline{T}$ = external temperature at the point considered. An arrangement complying with this relation was first used by the authors in 1932. It consists of small closely-spaced electrodes isolated from one another and placed all round the contour of the model. Each electrode is fed through a resistance R connected at its other end to a potentiometer set to a voltage $\overline{V}$, the values of R and $\overline{V}$ being such as to obtain the equivalent relations :

$$\overline{V} = \overline{T}, \text{ and } R = \lambda/(\alpha \, \rho \, dA)$$

where ρ = resistivity and dA = aera of an electrode. In this way, the potential $\overline{V}$ of each electrode gives the temperature distribution at the boundary, while the value of the current passing through each resistance R is in accordance with the heat flow. Strip electrodes can also be used to fulfil Dirichlet and Neumann type boundary conditions or even more complicated conditions.[12]

To illustrate the use of this method we shall consider a turbine disc, the temperature distribution of which was to be investigated. The two surfaces of the disc were cooled by a stream of fresh air coming out of the hub and impelled towards the periphery by centrifugal force. The air received a certain quantity of heat while flowing along the disc, and its temperature $\overline{T}$ at each point was a function of the flow velocity and the heat flow dissipated by the metal.

As this was a problem with rotational symmetry, a basin with a sloping bottom surface was used for the analogy. The boundaries were fitted with strip electrodes. The boundary condition was of the Fourier type, but $\overline{T}$ was not known beforehand and could only be determined by evaluating the heat flux from the disc, between the hub and each radius considered. In the analogy, this was equivalent to the sum of the currents produced by the strip electrodes situated within the corresponding interval. Correct settings were obtained by successive approximation, starting from a plausible temperature distribution. Measurements were taken of electrode potentials and currents and the summation provided the data for a new temperature distribution. The object of the study was to determine the effect of air flow velocity on cooling and the influence of varying transition coefficients on the heat gradient.

A similar procedure of successive approximations was employed for the study of the heat transfer in a semi-spherical mass of mercury in a problem related to the theory of mercury vapour rectifiers.[5] The mercury was contained in a heat-insulated glass tube with a hemispherical bottom (Fig. 1). The heat source is at the centre of the surface at the position of the cathode spot of the arc which is assumed to be stationary. The heat is dissipated by evaporation of mercury at the free surface. The heat transfer condition at each point of this surface can be expressed by the relation :

$$-\lambda \, dT/dz + A \, f(T) = 0$$

where λ is the conductivity of mercury, A a constant related to the heat of evaporation, and $f(T)$ a function defining the pressure of saturated vapour, as given by an experimental diagram. In the analogue, the above equation gives a relation between electrode current and potential and repeated adjustments give the correct settings. In this experiment it was possible to determine the influence of the diameter and temperature of the spot on the temperature distribution at the free surface and within the liquid and its effect on heat losses due to evaporation. The isothermals obtained are shown in Fig. 2, and the right-hand drawing shows with more detail the constant-temperature lines in the vicinity of the spot.

Two-dimensional problems involving media with different values of thermal conductivity λ can be represented by subdividing the basin into separate compartments. Each of these is filled to a height h with an electrolyte of conductivity σ, and the requirement is that the product $\sigma \, h$ should be proportional to λ. The partitions are of thin insulating material and carry a large number of conductive clips which are put on to ensure that equal values of potential are obtained on either side at each point of the separation line. If it is necessary to take account of a transition coefficient α, these clips are replaced by small electrodes on both sides of the partition. The electrodes are connected in pairs by means of resistors which have a value proportional to $1/\alpha$.

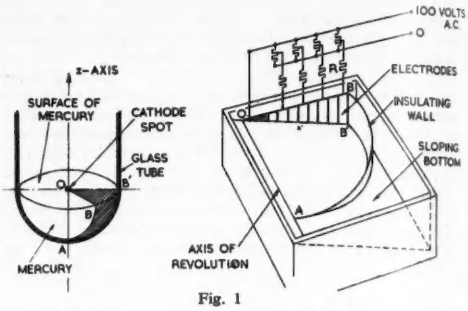


Fig. 1

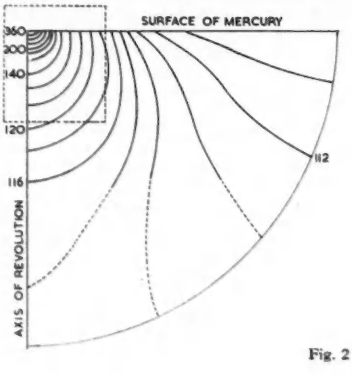
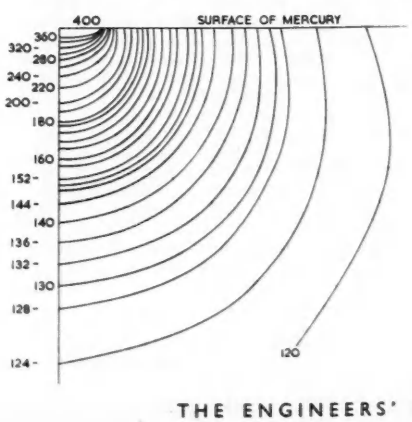


Fig. 2



In two-dimensional cases it is also possible to take account of a continuously variable conductivity, by using a basin with a curved bottom surface designed in such a way that the height of the liquid is proportional to λ at each point. This procedure is employed when the conductivity is a function of temperature. Each approximation requires a corresponding remodelling of the bottom of the electrolytic basin, with the data obtained from the previous experiment. This standard procedure is rapidly carried out with special equipment.

Electrically conductive paper with a graphite base can be used instead of an electrolytic basin for a rapid study of two-dimensional fields satisfying Laplace's equation. Details of this new dry-electrolyte method have been given by the authors in another paper.[8] The method is simple, rapid and economical. The isothermals can be traced directly on the conductive paper with adequate accuracy for a large number of applications. Fourier conditions can easily be simulated by incorporating strip electrodes and extending the field in linear strips which have a length L proportional to λ/α.

THE NETWORK METHOD

Network analogues of potential fields in two or three dimensions can be obtained with multi-mesh circuits consisting of electrical resistances of equal value. In cases of variable thermal conductivity, the value of each resistor should be inversely proportional to the corresponding value of λ for the mid-point of the side of the mesh considered.

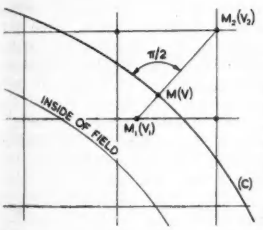


Fig. 3

The various boundary conditions previously mentioned can be represented more or less directly in the network analogy. The Dirichlet conditions are easily fulfilled, by raising the end-points of the boundary meshes to the required potentials by means of potentiometers. For Neumann and Fourier conditions, the arrangement is somewhat more complicated, particularly when the boundary intersects the network at some points. The normal derivative (Fig. 3) of the potential at a point M of the boundary-line (c) is represented by the ratio $\Delta V/\Delta n$ of the finite differences $\Delta V = V_1 - V_2$ and $\Delta n = \overline{M_1 M_2}$. The Fourier condition $AdV/dn = \overline{V} - V$ can then be expressed as

$$\left(\frac{A - \Delta n_1}{\Delta n}\right) \Delta V = \overline{V} - V_1$$

where $n_1 = \overline{MM_1}$. This condition cannot be satisfied automatically in a simple manner. The best procedure is to make adjustments with successive trials by varying the potentials at the external nodal points (for instance at M_2) until the potential differences ΔV and $\overline{V} - V_1$ verify the above equation. This method can be generalised for all types of boundary conditions with derivatives in any direction.[3]

Generally, the network analogy can be applied to any system representing an equation with partial derivatives which can be reduced to

$$\frac{\partial}{\partial x}\left(\lambda \frac{\partial \varphi}{\partial x}\right) + \frac{\partial}{\partial y}\left(\lambda \frac{\partial \varphi}{\partial y}\right) + \frac{\partial}{\partial z}\left(\lambda \frac{\partial \varphi}{\partial z}\right) = \varphi f + g,$$

where λ, f and g are functions of the co-ordinates.[9] The network must be laid out in such a way that: (1) each conductance representing the side of a mesh is proportional to the value of λ calculated for its mid-point, and (2) each nodal point must be fed through a conductance proportional to f, the other end of this conductance being raised to a potential proportional to $-g/f$.

A simple network analogue incorporating these features has been made by J. Broc[1] for the study of the temperature distribution along a bolometer wire heated by a high-frequency electric current passing through it.

A conductance network analyser has been designed at the C.N.R.S. laboratory. It incorporates a large portion of the equipment serving to set up the boundary conditions in electrolytic models. The analyser is designed so that it can be developed according to the type of problem to be investigated. At present, it includes six connection panels, each of which can be fitted with 450 fixed or variable resistors. These elements are inserted by means of standard plugs. The entire equipment uses ordinary standard-quality components which are easily interchangeable and available at low cost.

PROBLEMS WITH TRANSIENT CONDITIONS

Some general remarks are necessary in regard to large analysers. The analogue investigation of transient thermal conditions is based on the use of resistance-capacitance networks. Following the remarkable work of C. L. Beuken, begun in Holland towards 1934, a number of investigations (such as those of Kayan, Paschkis, and McCann) were initiated by various laboratories and resulted in the construction of large size analogue computers. These machines are described in an information report.[2]

These large machines are able to cope with nearly all types of thermal problems occurring in practice. The impressive equipment comprises a large number of panels with resistors and capacitors built as decade systems; it includes busbars for the building-up of analogue systems, current generators of various types, amplifiers, multipliers, recorders, cathode-ray oscilloscopes, manually-operated or synchronous commutators and switches, etc.

The accuracy of the results obtained with these machines depends primarily on the assumptions made in the analogue representation of the problem and, in particular, on the size of the meshes in the network, that is, the subdivision into small units of the body for which the temperature distribution is required. Moreover, to eliminate as far as possible errors inherent in the equipment itself, special precautions have to be taken. It is necessary to avoid insulation defects which are apt to occur in installations of this size, as well as condenser losses, which are of importance because the values of the capacitances used are high (in some experiments, these have to hold the charge for several minutes). The errors due to the use of sources of current with arbitrary time-characteristics must be minimised in order to approximate satisfactorily the input functions for the models, and there must be a minimum of disturbances in the measurement and recording to the various quantities.

DESCRIPTION OF A NEW SIMPLIFIED ANALYSER

An apparatus for the solution of non-stationary thermal problems was developed, originally in connection with the study of transient conditions in the walls of a rocket nozzle design.[10] Owing to limitations as regards size and cost, it was not intended to produce a universal machine, but the analyser which has been developed is sufficiently versatile to be of value in a large number of engineering problems.

The analyser operates in the following manner:— A sudden potential difference representing a sudden increase in temperature above a reference value is applied periodically at the input of a resistance-capacitance net-

work constituting the model. The model components are mounted on a table and directly connected to the apparatus, thus avoiding insulation defects. The time-unit is very short in all cases (an essential difference in regard to large machines), the capacitors and resistors have normal values for radio frequency components and the entire range of values can therefore be obtained without difficulty, with an accuracy of the order of 1-2 per cent or even 0·5 per cent. The leakages are practically zero and small-size analogues can be made for problems in two or three dimensions.[11]

The output signals of the analyser are indicated on an oscillograph screen by a method eliminating distortion. The unit stop function applied at the input takes up a sufficiently long period of time for the response signal from the measuring position to reach its asymptotic value. The time required for the stop function varies with the section considered and may be difficult to predict in a somewhat complicated model. It can be determined, however, for each section by considering the steepness of the curve of temperature rise in relation to its asymptotic value.

The transient is repeated at a certain frequency to enable accurate point-by-point measurements to be obtained. Before repetition of the cycle, the entire network is cleared by feeding an opposing signal voltage into the input during a relatively long period of time. Thus, the network is charged for a fraction (for instance, one-fourth) of the period only, and during this time the measurement is made, the remaining time being used to bring the network down to zero voltage.

A multi-channel rotary commutator switch selects the various input and output signals to be sent through the network or to the oscilloscope unit. The period is thus divided by the selector into a number of fractions (four or more), which make it possible to obtain, taking account of persistence of vision and tube properties emphasised by coloured filters, a simultaneous image of the various response signals giving instantaneous information on the conditions in the entire system as well as the effect of individual parameters.

All voltages are applied directly to the plates of the cathode-ray tube and, therefore, the corresponding signals are without phase or amplitude distortion. On the oscillograph screen, one sees the response curve for the measuring point under investigation, as well as the signal indicating that the network is cleared at all points at the end of each period. The screen also shows the time and temperature axes, the asymptotes and the calibration markings (as points or intersection of the axes) which make it possible to follow the curve point by point. The time and temperature co-ordinates are measured by a double null-balance method. Thus, any distortions due to the tube are eliminated without requiring corrections of visual readings or photographic records. The x- and y-axis controls give time spread and amplitude gains required for detailed examination. The co-ordinates of the required points are accurately indicated by two calibrated potentiometers.

The equipment includes a precision type frequency-meter and circuit eliminating any effects due to mains frequency variations. Coincidence of the linear time-scale and the mechanically-controlled time-sweep pulses is obtained by an initial adjustment of two controls of a synchronising circuit.

APPLICATIONS AND ACCURACY OF RESULTS

In order to assess the accuracy which could be expected with this analyser, comparisons were made with the results of theoretical calculations for simple cases. Several authors[6,14] have determined the increases in temperature as function of time which occur in bodies of simple geometrical shape, such as plates, cylinders and spheres, when their surface is subjected to a sudden rise in temperature.

Network models for the plate, cylinder and sphere were therefore built up at the laboratory using 12 subdivisions for the plate and the cylinder, and only six for the sphere. The results obtained for these three bodies are illustrated in Fig. 4, for a transition coefficient equal to unity. It is seen that very close agreement is obtained, in all three cases, between calculated and measured results.

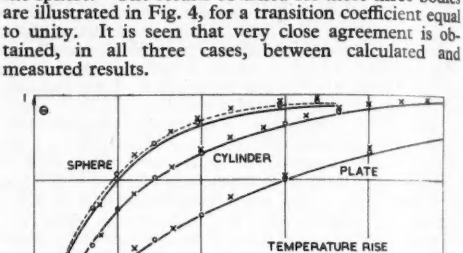


Fig. 4

In the difficult case of the sphere, the integral of the curve up to any time t represents, apart from a constant factor, the quantity of heat which has entered the body up to that instant. In the example chosen, the relative heat flux tends towards unity as the time increases towards infinity. The integration of the analyser curve gives 0·894 whereas the integration of the curve given by Grober and Erk gives 1·05 for the same conditions.

In order finally to obtain a comparison in which no assumptions as regards subdivisions are required for the setting up of the analogue network, the simplest case was taken, viz., the charging of a capacitor through a resistance. The measured values showed excellent agreement with the theoretical values, and it would appear that the errors due to the apparatus itself are not much greater than 0·1 per cent.

The analyser could be expanded by the addition of various units for different types of input signals in order to study transient response in a general way as in larger machines. The apparatus, however, is already applicable to a wide variety of problems, particularly if the possibilities of symbolic calculus are used for the study of transient conditions and the relations between output and input signals. By means of this analyser it is thus possible to consider the study of further types of heat exchange problems, such as occur when the heat flow varies in accordance with various experimental laws based on calculated charts.[13]

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Cutting Forces and Temperatures when Milling with Carbide Cutters

By H. Opitz* and J. Kob.†

The introduction of carbides in continuous cutting operations, e.g., turning, was accomplished without encountering great obstacles in regard to tooling. On the other hand, application of carbides to interrupted cutting, e.g., milling, required extensive testing. Difficulties resulted from the great brittleness of carbides and the concommitant sensitivity to shock and vibration. It was important, first of all, that the initial shock at each engagement of a tooth occur in a zone away from the sensitive cutting edge and, secondly, that the shape of the cutting edge be made as strong as practical. The consequence was that tools which had true negative rake angles were applied and only then was it possible to mill some materials, especially steels, with carbides.

Tests conducted during the last two years in the Laboratory for Machine Tools and Production Technique at the Technical University at Aachen were concerned primarily with the angles of the tool. The design of the cutting edge with regard to the instant of entrance into the workpiece is especially important since in most cases the type of entrance is a determining factor in tool life. It was found that a relatively long period of entering, the time between the initial and complete contact of workpiece and tooth face, reduces the wear at the cutting edge. Relatively long periods of entering time can be obtained through proper choice of negative rake angles and favourable positions of the cutter axis with regard to the workpiece surfaces.

After the effects of impact and time of entering with regard to tool life and tool wear had been determined, further tests were concerned with the determination of optimum tool angles for milling of steel and cast iron. Independent of the strength properties of the steels tested, low values of wear for very definite rake angles were established. These optimum rake angles for steels of tensile strength properties between 50,000—140,000 psi lie within the limits of —7 to —13 degrees. It was established that generally with increasing strength properties and cutting speed, tools with larger negative angles show less wear. Further tests were concerned with optimum rake angles for different types of cast iron. For medium to hard types these are between 0 and —5 degrees. With hard cast irons of 95 Shore Scleroscope, satisfactory results could be obtained only by making the rake angle —15 degrees. For softer types of grey cast iron which require only small cutting forces, rake angles with small, positive values can be chosen. Negative rake angles require more power amounting to about one per cent for each degree. Grinding a negative ridge at the cutting edge of a positive rake tool will reduce this power increase. Measurements for the application of a negative ridge in comparison to a true negative rake angle resulted in a decrease of as much as 22 per cent in the power requirements of the drive motor. Regrinding of a tool with such a ridge is more economical. To make the cutting edge as strong as possible the relief angle should be chosen as small as the operation will permit.

The cutting speed and feed per tooth also had an influence on wear. For milling with carbides, the following cutting speeds can be considered economical:

For low carbon steels 500 to 720 fpm
For medium carbon steels 400 to 500 fpm
For higher carbon steels 300 to 400 fpm

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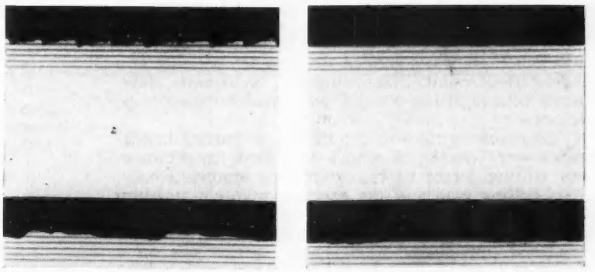
These high cutting speeds require a modern, high-powered rigid milling machine. It is especially important when milling with carbides to select the proper feed. Feeds of 0·008 to 0·012 ipt for steel and up to 0·016 ipt for cast iron have proved economical. Feeds below 0·004 ipt should be permissible only when a high surface finish is required. At feeds below 0·002 ipt tool wear increases very rapidly. Temperature measurements taken during operations at these small feeds, in which the tool is practically scraping rather than cutting, were very high. Depth of cut has an effect similar to feed per tooth; too small a depth of cut causes great wear and is therefore uneconomical.

Through the choice of suitable cutting speeds and feeds, surface finishes can be obtained in milling which are similar to those obtained in grinding. Diagrams of a milled surface are shown in Fig. 1. Steel of 128,000 psi tensile strength was milled at a cutting speed of 820 fpm and a feed of 0·0024 ipt. The two diagrams on the left show the profiles of the milled surface in directions radial to the cutter axis. The two diagrams on the right show profiles in the direction of feed, after the milling cutter had heeled over the surface. The evaluation of the first two diagrams gives peak to valley roughness measurements of 0·000120 to 0·000160 in. similar to those for grinding. In the diagrams on the right the values are even below 0·000040 in. The waviness of the surface, which depends upon the condition of the machine and the accuracy of the milling cutter, is only about 0·000080 in.



(a) (b)

Fig. 1. **Roughness diagram of a milled surface as produced with a "Forster" surface measuring instrument.**

(a) Depth of roughness 0·000120 to 0·000160 in. (measured in a direction radial to the axis of the face mill)

(b) Depth of roughness 0·000040 in. (measured in direction of feed). Workpiece material, steel of 128,000 psi T.S.; cutting speed, 820 fpm; feed per tooth, 0·0024 in.

After the most important factors which influence the entrance of the cutter had been defined, the milling operation proper was more closely investigated. Here it was of interest, as in any other metal cutting operation, to determine primarily the cutting forces and cutting temperatures since these are of paramount concern in the design and economy of the machine and tool. Beyond that, the variations in the values of the cutting forces and cutting temperatures during a milling operation must be considered. Articles have been published fairly recently in which it was stated that, if rotating tools were operated beyond a certain high cutting speed, the cutting temperatures would decrease. It was also stated that, with a further increase in cutting speed, cutting temperatures would be as low as those at ordinary cutting speeds.[1] This was a reference to the patent** of Salomon which was issued to the Krupp Company in 1925.

**German Patent No. 523,594.

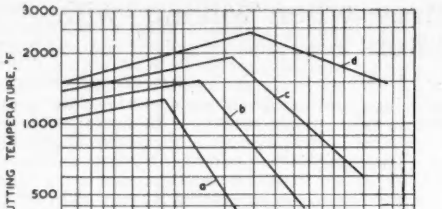


Fig. 2. **Cutting temperatures in relation to cutting speed.** (a) Aluminium ; (b) brass ; (c) bronze ; (d) SAE 1050 type steel.

Temperature curves for various materials from one such publication are shown in Fig. 2. Cutting temperatures for aluminium, brass, bronze and steel versus cutting speed are plotted on a log-log scale. With all these materials there was a sudden drop in temperature at a characteristic point. Unfortunately, no definite statements with regard to tool life were made in these publications.[2,3]

To check on the two conditions, measuring instruments were developed which permitted temperatures and cutting forces to be determined simultaneously. Steel cutting grades of the tungsten-titanium-tantalum type of carbides were used in all these tests. The equipment and machines used in this work have been described previously.[4] Tests were carried out on a Heller milling machine of the FH 120 type with a drive motor capacity of 36 hp and a maximum spindle speed of 1500 rpm. With a face milling cutter which had a diameter of 11½ in., it was possible to obtain a cutting speed of 4500 fpm. Fig. 3 shows the cutting temperatures. Steels of the SAE 1010* and SAE 1035† types were milled. The results do not indicate a temperature decrease for any of these cutting speeds. While the maximum cutting temperature was about 2000° F when milling steel of the SAE 1010 type, it increased to 2400° F when milling steel of the SAE 1035 type. The tool life was therefore very short with these high cutting speeds and temperatures. The sudden increase in the temperature for the SAE 1010 type of steel at about 600 fpm takes place with the transition from a short segmented chip to a long continuous chip. When milling steel of the SAE 1035 type at high cutting speeds, temperatures which came close to the melting point of the milled material were obtained. There must, therefore, be a liquid phase between the chip and tool surface at these high cutting speeds. A close inspection of Fig. 2 shows that the bend of the temperature curves is close to the melting point of the particular workpieces. Since these temperatures were determined by measurements of thermal voltages, it was necessary to check upon the relationship of thermal voltages to actual temperatures in the vicinity of the melting point. From calibration curves for thermal elements,[5] it can be seen that the thermal voltage decreases above the melting temperature. It can therefore be stated that measurements close to the melting point will show thermal voltages but not true cutting temperatures.

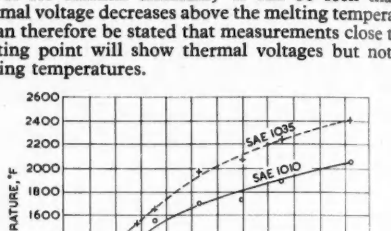


Fig. 3. **Cutting temperature in relation to cutting speed when milling SAE 1010 and SAE 1035 steel.** Rake angle, —16 deg. ; depth of cut, 0·120 in. ; feed per tooth, 0·004in.

As long as the melting points of workpiece materials, e.g., aluminium, are below the point at which carbides lose their cutting hardness, it is possible to increase the cutting speeds at will. Because of the fluid friction between the chip and the surface of the tool no appreciable temperature increase will occur.

Further tests were concerned with the measurement of cutting forces and cutting temperatures at lower and medium cutting speeds. At first, these values were determined for segmented chips. Fig. 4 shows the cutting force and temperature when milling SAE 1010

* 0·05–0·15 C, 0·30–0·60 Mn.
† 0·30–0·40 C, 0·60–0·90 Mn.

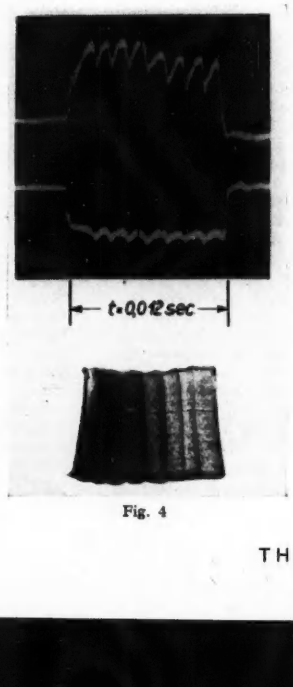


Fig. 4

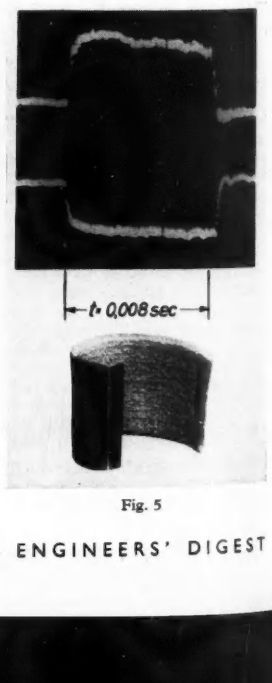


Fig. 5

Fig. 4. **Changes in cutting force and cutting temperature when forming a segmented chip.** Workpiece material, SAE 1010 steel ; carbide tool cutting speed, 380 fpm ; depth of cut, 0·120 in. ; feed per tooth, 0·004 in. In the oscillogram ; tangential cutting force (upper trace) 135 to 175 lb. ; cutting temperature (lower trace) 1166 to 1418° F.

Fig. 5. **Cutting force and cutting temperature when forming a continuous chip.** Workpiece material, SAE 1010 steel ; carbide tool cutting speed, 580 fpm ; depth of cut, 0·120 in. ; feed per tooth, 0·004 in. In the oscillogram : tangential cutting force (upper trace) 145 lb ; cutting temperature (lower trace) 1418° F.

type steel at 380 fpm cutting speed. Below the cathode-ray oscillogram the chip which was formed during this interval is shown. The cutting force varied between 135 and 175 lb during the formation of each segment, while the cutting temperature varied between 1166 and 1418 F. The exact evaluation of the enlarged oscillogram brought out that the cutting force is at a minimum when the temperature reaches a maximum. This observation can be explained as follows: After the cutter tooth enters the workpiece, the material is compressed. This compression requires an increase in the cutting force up to a point at which a shearing stress large enough to fracture the workpiece material is reached. At the instant of shearing, the cutting force decreases suddenly but the segment of the chip begins to slip on the rake surface of the tool. Because of this, an additional amount of heat due to friction is generated which causes again an increase in the cutting temperature. This oscillation between maximum and minimum cutting force and cutting temperature repeats itself frequently while a chip is being formed.

Conditions are different when a continuous chip is formed. This is illustrated by the following case in which the cutting speed had been increased to 580 fpm. The oscillogram in Fig. 5 shows that with a continuous chip, neither the cutting force nor the cutting temperature change very much. The chip as formed under these conditions is shown below the oscillogram.

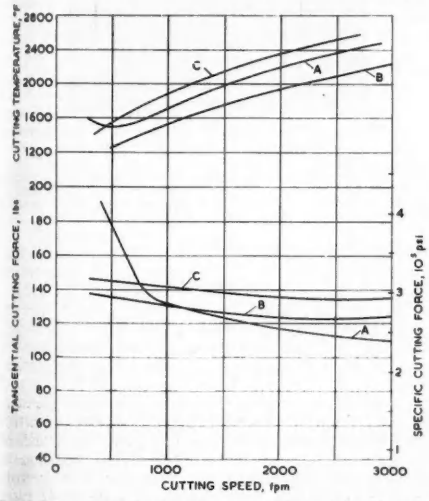


Fig. 6. **Tangential cutting force, specific cutting force and cutting temperature in relation to cutting speed when milling steel.**
(A) SAE 1010; (B) SAE 1035; (C) SAE 1060 steel; depth of cut, 0·120 in.; feed per tooth, 0·004 in.

Wear at the cutting edge is quite different with the different chip formations. This was especially noticeable when milling SAE 1010 type steel which had a great tendency to stick or weld to the tool tip, causing a crater of 0·020 in. depth on the tool surface. When a continuous chip was formed no crater was observed on the tool after the same amount of material had been cut. In a further series of tests, the relations of the cutting force and cutting temperature to cutting speed, depth of cut and feed were investigated. Fig. 6 shows the changes of cutting force and cutting temperature in relation to cutting speed for various kinds of steel. Again it can be seen that changes occur during the interval of chip formation from a segmented to a continuous chip when milling steel of the SAE 1010 type. Within the speed range in which segmented chips are formed, the main cutting force and the specific cutting force decrease considerably. This tendency of decreasing cutting force, although less pronounced can also be observed in the speed range in which a continuous chip of SAE 1010 type steel is formed. There was much less variation of the cutting force when milling steel of the SAE 1035 and SAE 1060* types. The cutting temperature increases continuously with the cutting speed except for a certain amount of variation during the changes in chip formation for the SAE 1010 type steel.†

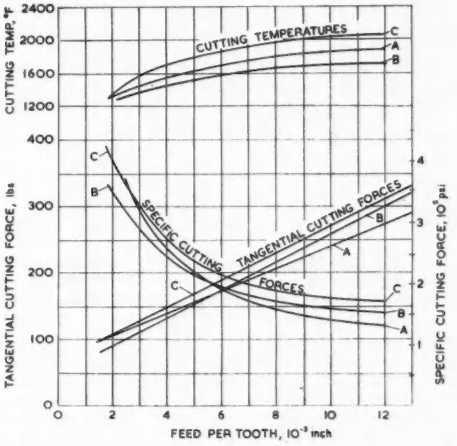


Fig. 7. **Tangential cutting force, specific cutting force and cutting temperature in relation to feed per tooth.**
Materials same as those in Fig. 6. Cutting speed, 740 fpm; depth of cut, 0·120 in.

The influence of feed upon cutting force and cutting temperature can be seen in Fig. 7. When milling steel with carbides the feed was varied within the limits of 0·002 to 0·012 ipt. The cutting force increased with increasing feed while the specific cutting force decreased. It is essential to note that the cutting temperature increased less rapidly with an increase in the feed than with an increase in cutting speed.

The efficiency and economy of a milling operation can be increased in three ways, viz.:—(1) greater depth of cut, (2) higher cutting speed, and (3) increased feed. Of these three, the depth of cut is usually predetermined so that the operation can be improved only by increasing the cutting speed or the feed. In both cases a decrease in the specific cutting force can be obtained. However, the cutting temperature increases more rapidly with increasing cutting speed than with increasing feed. Since cutting temperature is a determining factor in tool life, it is more practical to increase the efficiency by increasing the feed rather than by increasing the cutting speed. Figs. 6 and 7 may be used as explanatory examples. If the volume of chips per unit of time is doubled by increasing the cutting speed for steel from 740 to 1480 fpm, the cutting temperature of the SAE 1035 type will increase by about 21 per cent from 1450 to 1760° F. In doubling the efficiency by doubling the feed from 0·004 to 0·008 ipt, when machining the same type of steel at a cutting speed of 740 fpm, the cutting temperature will increase only 14 per cent from 1450 to 1650° F. However, the amount of feed is dependent upon the surface finish required as well as upon the horse-power and rigidity of the milling machine.[4]

The third influence, depth of cut, was also investigated. The results can be seen in Fig. 8. For a

*0·55–0·70 C, 0·60–0·90 Mn.

†The steel actually used in these tests was a low carbon steel similar to structural steel and showed a strong tendency to form a built-up edge.

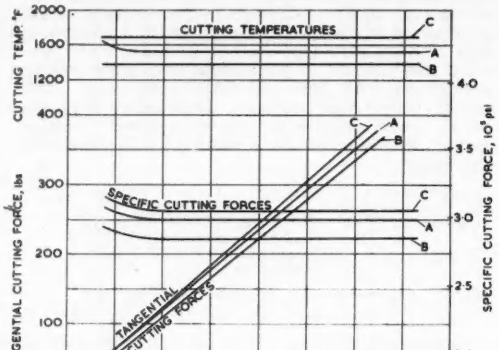


Fig. 8. **Tangential cutting force, specific cutting force and cutting temperature in relation to depth of cut.**
Materials same as those in Fig. 6. Cutting speed, 740 fpm; feed per tooth, 0·004 in.

cutting speed of 740 fpm (continuous chip) the depth of cut was varied between 0·040 and 0·360 in. With an increase in depth of cut the cutting force increases linearly while the specific cutting force remains practically constant except for very small depths of cut at which the effect of the blade face is more noticeable. The cutting temperature remains constant also within the limits of the investigation. It can be seen from Fig. 6 that the cutting force and cutting temperature for SAE 1010 type steel are much higher when forming segmented chips than when forming a continuous chip at a slightly faster cutting speed. The same phenomenon prevailed at various depths of cut. The results show that the depth of cut must be chosen in relation to the horsepower and rigidity of the machine and as deep as tool and workpiece will permit.

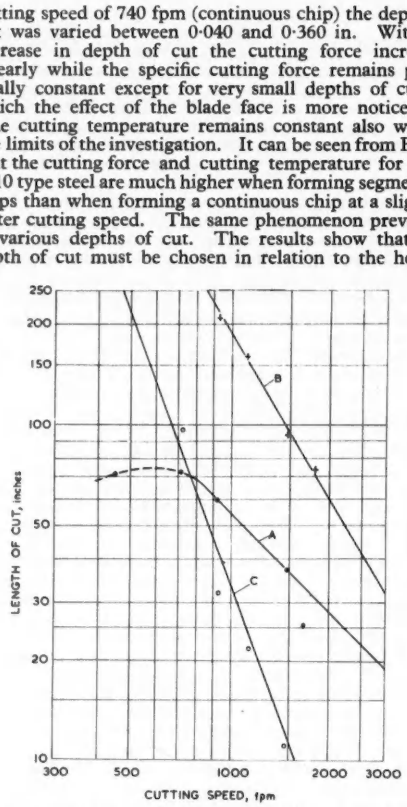
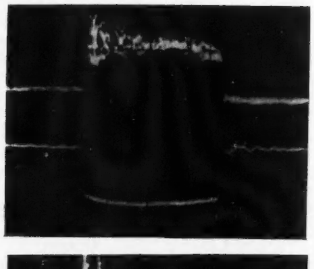


Fig. 9. **Length of workpiece milled with a single-tooth cutter in relation to cutting speed.**
Materials same as those in Fig. 6. Feed per tooth, 0·004; rake angle, —13 deg.
Cutters were removed for resharpening when depth of crater reached 0·008 in. as determined with a "Schmaltz" surface measuring instrument.

Very high cutting speeds cause a comparatively short tool life due to the higher temperatures at the cutting edge. In Fig. 9 are plotted the lengths of workpiece machined in relation to cutting speed when milling workpieces $1\frac{9}{16}$ in. wide at 0·120 in. depth of cut with a single tooth cutter.



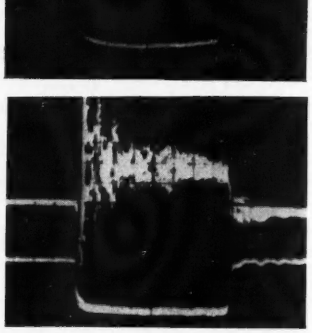


Fig. 10. **Maximum variation of cutting force in relation to overhang of milling cutter tooth.**
Carbide tips brazed to a steel shank inserted in face mill body. Upper oscillogram for 1 in. overhang: Cutting Force (upper trace) between 45 and 220 lb in compression only. Lower Oscillogram for $1\frac{1}{4}$ in. overhang: Cutting force (upper trace) varied between 385 lb in compression and 165 lb in tension.

As has been mentioned before, carbide tools are very sensitive to vibrations. By changing the amount of overhang of the teeth the effect of changes in the natural frequency of the tool upon the cutting force was investigated (Fig. 10). The vibrations which occur due to the impact of the tool upon the workpiece cause a change in the cutting force in relation to the natural frequency. As the upper oscillogram of the cutting forces shows, the vibrations are damped partially because of friction during the cut. Above a certain amount of overhang, more than 1 in., the amplitudes of the vibrations became so great that, in addition to fluctuating compressive stresses, there were also alternating compressive and tensile stresses. In most cases this is related to breakage of the cutting edge or to the complete destruction of the carbide tip. The tests also show a certain influence of the material to which the carbide tip has been fastened in relation to damping capacity and therefore the effect upon tool life. It is intended to investigate these questions in further, future tests.

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The Effect of Mechanical and Electrolytic Polishing on the Micro and Macro Hardness of Metals

By T. GEIGER. (From *Technische Rundschau Sulzer*, No. 3, 1952, pp. 17-23, 14 illustrations.)

Micro hardness is becoming increasingly important in metallographic testing, but it is greatly influenced by the method used for polishing the test pieces, and by the crystal orientation as well as the actual hardness testing procedure. These influences are discussed in this paper, and results of various tests, supported by microscopic and X-ray examinations, are given.

THE preparation of metallic test pieces for microscopic structure investigation generally involves mechanical polishing. This procedure, however, results in a deformed layer on the surface of the test piece, and this layer is detrimental for certain work. The most noticeable effect of mechanical grinding and polishing is a surface consolidation and strengthening, shown as an increase in hardness. Macro hardness is only slightly affected, because of the relative thinness of the deformed layer. Micro hardness, where the penetration of the indentor is measurable only in microns, is affected to a much greater extent. In view of the increasing importance of micro hardness testing, it is desirable to determine the degree of hardness increase due to mechanical polishing for various materials. For comparison purposes, the micro hardness of an undeformed polished surface can be obtained by electrolytic polishing. A procedure developed by P. Jacquet enables the deformed surface layer to be removed by electrolytic dissolution. The pre-ground test piece is thus partially dissolved as an anode, using a suitable electrolyte. Under certain conditions of current density and temperature, protruding parts of the surface are dissolved more rapidly than the depressions, so that the resulting surface is smoothly polished.

The following materials were selected for the hardness investigation on mechanically and electrolytically polished test pieces :

(1) Austenitic Ni/Cr steel, type 18/8, solution treated at 1100° C.
(2) Electrolytic iron.
(3) Carbon steel, type C 5.

Materials (1) and (3) are monophase and therefore lend themselves to direct comparison of macro and micro hardness.

TEST PROCEDURE.

The customary procedure was used for mechanical polishing. The test pieces were treated with abrasive paper up to grade 600 (Continental) and then polished, using a cloth buff and alumina. For electrolytic polishing, the test pieces were rough polished with abrasive paper up to grade 400 and then treated in the " Electric-Polisher," manufactured by Messrs. Buhler, of Chicago, U.S.A. De Sy's alcoholic perchloric acid of the following composition was used as the electrolyte :

66 cc perchloric acid (60 per cent)
134 cc water
775 cc alcohol
25 cc ether.

A Hanemann type D 30 hardness tester was used for micro hardness testing. This instrument has a Vickers pyramid type diamond indentor built into the front lens of the objective, to ensure great location accuracy. The indentations were measured by the diagonal method ; this, as described below, possesses certain advantages over the area measurement method.

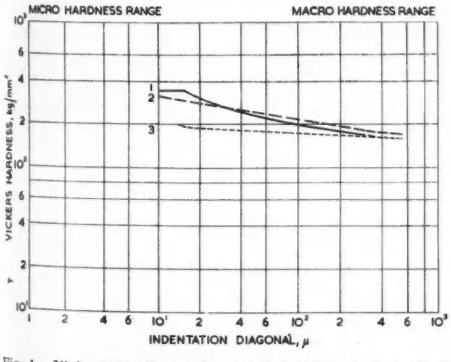

Fig. 1. **Vickers hardness of mechanically and electrolytically polished 18 Cr/8 Ni steel in relation to the indentation diagonal.**
(1) Mechanically polished.
(2) Electrolytically polished (20 seconds).
(3) Electrolytically polished (80 seconds).

HARDNESS TEST RESULTS AND THEIR INTERPRETATION.

Vickers hardness values for the Ni/Cr steel are plotted against the diagonal of the indentation in Fig. 1. Considerable differences between test pieces polished mechanically and those treated electrolytically for 80 seconds are noticeable in the micro hardness range. The increase in hardness due to mechanical polishing, at small test loads, is in the order of 150 kg/mm², this being equivalent to an 80 per cent increase. A noticeable difference is also present in the macro hardness range when small loads are used. On this austenitic steel, mechanical polishing causes considerable surface strengthening. The depth of the affected layer must be relatively great, since the undisturbed material was not reached after the short, 20-second electrolytic treatment.

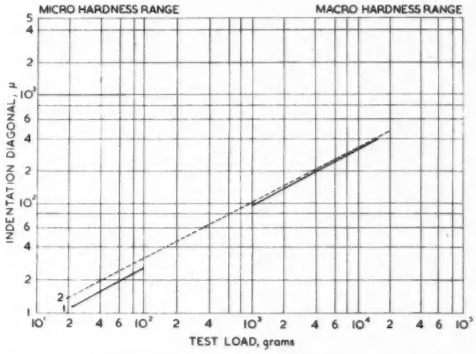

Fig. 2. **Indentation diagonal in relation to the test load for 18 Cr/8 Ni steel.**
(1) Mechanically polished, $n = 1{\cdot}77$ (micro hardness), $n = 1{\cdot}87$ (macro hardness).
(2) Electrolytically polished (80 seconds), $n = 1{\cdot}91$.

The micro hardness of the test piece with the undisturbed surface is still noticeably influenced by the load and, thus, does not conform to Kick's law of similarity. When plotting the indentation diagonal against the load on a double logarithmic scale, a straight line is obtained. The hardness, therefore, follows Meyer's exponential law, see Fig. 2.

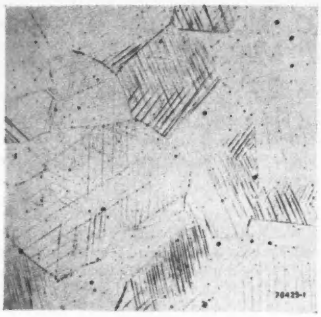

Fig. 3. **Photomicrograph of an electrolytically polished surface on the 18/8 steel test piece, showing slip lines in the austenite crystals. The undisturbed surface has therefore not been reached after the short, 20-second electrolytic treatment. (× 250 × 0·62.)**

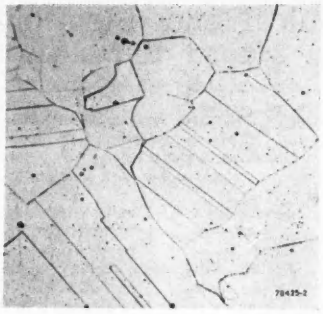

Fig. 4. **Photomicrograph of an electrolytically polished surface on the 18/8 steel test piece, showing austenite crystals with twin laminae but no slip lines. The deformed layer has been completely removed after the 40-second electrolytic treatment. (× 250 × 0·62.)**

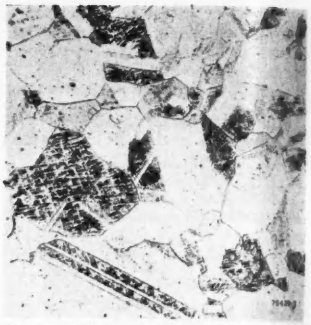

Fig. 5. **Photomicrograph of a mechanically polished surface on the 18/8 steel test piece, showing distinct slip lines due to deformation. (× 100 × 0·62).**

In the case of the electrolytically treated test piece, the micro and macro hardness results lie on the same straight line, and extrapolation is thus possible. The graph for the mechanically polished specimen, however, shows a distinctly different gradient for the micro and macro hardness ranges.

The exponent n in the equation $P = a\,d^n$, where P = test load, a = material constant and d = indentation diameter, is clearly different for the mechanically and electrolytically polished test pieces. The value of constant $n = 1{\cdot}91$ for the electrolytically test piece approaches 2; this latter value would satisfy the law of similarity. The discrepancy is much more pronounced for the mechanically polished test piece with $n = 1{\cdot}77$ to $1{\cdot}87$.

TABLE I. MICRO HARDNESS OF Ni/Cr AUSTENITE CRYSTALS HAVING DIFFERENT ORIENTATION IN RELATION TO THE POSITION OF THE INDENTOR PYRAMID, SHOWING INFLUENCE OF MEASURING METHOD.

Measurement of indentation diagonals	Hardness of crystals Nos. 1-8, in kg/mm²							
	1	2	3	4	5	6	7	8
Pyramid position								
0°	188	200	205	203	216	214	214	230
15°	190	192	205	203	206	210	210	230
30°	194	188	200	206	206	207	218	230
45°	192	190	200	206	196	205	216	222
60°	197	192	192	200	206	206	214	218
75°	195	192	196	203	218	210	214	217
Average hardness of polished surface	193	194	196	203	208	209	214	225
Maximum hardness variation from average value —	188	188	192	200	196	205	210	217
+	197	200	205	206	218	214	218	230
Measurement of indentation area								
Pyramid position								
0°	180	180	182	190	184	186	198	203
15°	175	182	180	182	200	198	218	208
30°	174	191	188	185	215	192	208	208
45°	183	192	188	185	196	191	196	208
60°	198	188	192	191	191	191	196	203
75°	200	174	188	192	184	192	198	206
Average hardness of polished surface	184	185	186	187	195	191	202	206
Maximum hardness variation from average value —	174	174	180	182	184	186	196	203
+	200	192	192	192	215	198	218	208

The increase in micro hardness due to mechanical polishing is also noticeable in the case of electrolytic iron; it is in the order of 15 per cent and is therefore considerably less than that for the austenitic Ni/Cr steel. This fully agrees with the known fact that austenite has greater strain hardenability than ferrite.

The hardness increase is even smaller for the ferrite in carbon steel. The micro hardness of the mechanically polished surface is only about 8 per cent higher than that of the undisturbed surface. The exponent n is smallest for the mechanically polished surface, as with the Ni/Cr steel and the electrolytic iron.

The smaller increase in hardness of the ferrite in carbon steel in comparison with the electrolytic iron could be due to a certain degree of protection of the ferrite particles by hard perlite areas during grinding deformation.

STRUCTURE INVESTIGATION.

The changes in the surface structure due to mechanical grinding and polishing can sometimes also be established microscopically. Plastic deformation of the austenitic materials is evidenced by the appearance of slip lines in the individual crystals, Figs. 3 to 5.

X-RAY DIFFRACTION TESTS.

The hardness and structure investigations were supplemented by X-ray diffraction tests. This method is particularly suitable for examining the crystal structure of surface layers due to the slight penetration of the soft X-rays. The diffraction patterns shown in Figs. 6 to 11 fully support the micro hardness test results. They also prove that electrolytic polishing, if maintained for an adequate period, enables the undisturbed material to be reached.

THE EFFECT OF CRYSTAL ORIENTATION ON MICRO HARDNESS.

Hardness is a purely vectorial property of crystals, and it can therefore be expected that the hardness of individual crystals will be influenced by the direction of penetration of the indentor. Crystal orientation does not play an important part in macro hardness testing, as the indentation generally covers a number of crystals. In micro work, however, the indentations are mainly made in individual crystals, and here the hardness anisotropy results in distortion of the indentation area. The effect of crystal orientation was investigated in a coarse-grained austenitic Ni/Cr steel. An undeformed surface was produced electrolytically and the position of the individual crystals was determined by X-ray diffraction photographs using the method according to Laue. The orientation of eight crystals was determined

Fig. 6. **X-ray diffraction photograph of an electrolytically polished surface on the 18/8 steel test piece : the sharp interference marks indicate undeformed surface crystal condition. (Cr-radiation reflection).**

Fig. 7. **X-ray diffraction photograph of a mechanically polished surface on the 18/8 steel test piece : the blurred, ring-like interference marks indicate relatively marked cold deformation of the polished surface.**

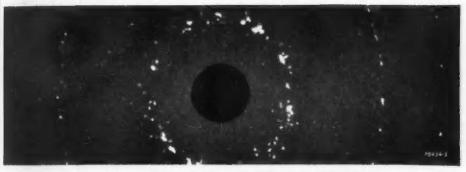

Fig. 8. **X-ray diffraction photograph of an electrolytically polished surface on electrolytic iron : the sharp interference marks indicate undeformed surface crystal condition.**

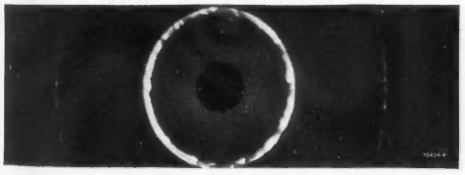

Fig. 9. **X-ray diffraction photograph of a mechanically polished surface on an electrolytic iron test-piece : distinct peripheral spreading of interference marks into rings indicates plastic deformation of surface layers during the mechanical polishing process.**

Fig. 10. **X-ray diffraction photograph of an electrolytically polished surface on a carbon steel test piece : perfectly sharp undisturbed crystal condition of surface ferrite grains.**

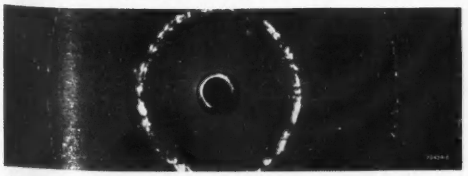

Fig. 11. **X-ray diffraction photograph of a mechanically polished surface on a carbon steel test piece : slight blurring of interference marks indicates less severe cold deformation of ferrite than with the electrolytic iron.**

and micro hardness tests were made with six different pyramid positions at the following angles : 0, 15, 30, 45, 60, and 75 degrees. Each indentation was measured by two methods : (1) Diagonal measurement as in Vickers hardness tests and (2) area measurement using a Zeiss ocular planimeter. The results are summarised in Table I ; the influence of the measuring method used is particularly interesting.

(a) INFLUENCE OF MEASURING METHOD.

Area measurement generally emphasises the differences between the various pyramid positions rather more than the diagonal method. Furthermore, with the former method, the average hardness values are lower throughout. This is caused by the concave outlines of the majority of the indentations due to slippage during plastic deformation. The indentation area is therefore larger than the square on the diagonals. Diagonal measurement is preferable in the case of easily deformed materials, as the hardness values are less susceptible to the position of the indentation pyramid.

(b) INFLUENCE OF PYRAMID POSITION AND OF CRYSTALLOGRAPHIC ORIENTATION OF TEST SURFACE.

The following conclusions are established by considering the hardness values in conjunction with the crystallographic orientation of the tested crystals, as shown in Fig. 12.

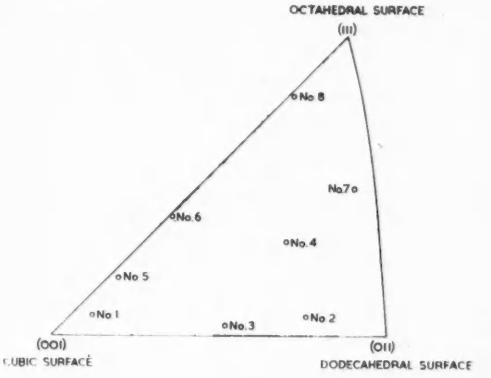

Fig. 12. **Average hardness values of the eight austenite surfaces as a function of their crystallographic orientation. The values in brackets give the maximum hardness variation of one surface with different indentor pyramid positions.**

No. 1 HV 193 (188-197)	No. 5 HV 208 (196-218)
No. 2 HV 194 (188-200)	No. 6 HV 209 (205-214)
No. 3 HV 196 (192-205)	No. 7 HV 214 (210-218)
No. 4 HV 203 (200-206)	No. 8 HV 225 (217-230)

(1) Hardness variations in relation to pyramid positions are generally larger with similarly orientated crystals, than with crystals having different orientation. In these cases, the dependence of hardness on the direction of measurement exceeds the average hardness variations between differently orientated surfaces.

(2) Hardness values of surfaces having obviously different orientation lie outside the variations of values caused by different pyramid positions on the same surface. The effect of crystal orientation is greater in these cases than the hardness anisotropy of individual surfaces.

(3) The variation of micro hardness in relation to crystallographic position of the polished surface is of some interest. The maximum hardness is found near the octahedral surface (111), whereas the cubic surface (001) shows the minimum hardness.

The above results show, that the micro hardness in the examined Ni/Cr steel is affected by crystal orienta-

tion, as well as by the position of the indentor pyramid. In order to arrive at an average value, it is therefore necessary to obtain several indentations in various crystals.

SUMMARY.

Micro hardness is becoming increasingly important in metallographic material testing. The effect of mechanical polishing on the micro and macro hardness of several metals has been discussed. Undeformed surfaces were produced by electrolytic polishing, and hardness tests on these were compared with those on mechanically polished surfaces. The comparison clearly showed a considerable surface hardening due to mechanical grinding and polishing, particularly with the austenitic steels. Micro hardness test results were confirmed and supported by micro-structure examinations and X-ray diffraction tests.

HOLLAND

Remarks on Spray Drying

By C. BERGSOE. (From *De Ingenieur*, Vol. 64, No. 29, July 18, 1952, pp. 71-76.)

Spray-drying processes, in which the moisture of a substance is removed through evaporation by atomising the liquid in a heated air stream, have been used for many years, and patents relating to spray-dried milk-powder manufacture can be traced back to about 1870. *It is only recently, however, that this process has been the subject of systematic research. The present report deals with spray drying from the point of view of the design and use of spray-drying plant.*

HEAT BALANCE AND HEATING EFFICIENCY

The specific heat of air is 0·24 cal/kg °C. Therefore, if t is the temperature of the air drawn into the system, and T_i the temperature of the heated drying air before the drying, the heat taken into the plant is

$$q_{in} = 0{\cdot}24\,t + 0{\cdot}24\,(T_i - t) = 0{\cdot}24\,T_i \quad [\text{cal/kg}_{air}].$$

The heat of the vapour formed during the drying process is $q_v = 595x$ (595 being the number of calories required to evaporate 1 kg of water at 0° C). An additional amount of heat $q_{vo} = 0{\cdot}46x\,T_o$ is needed to heat the vapour to the outgoing air outlet temperature T_o, the specific heat of water vapour being 0·46 cal/kg °C. The outgoing air, apart from the vapour, carries away a further amount of heat $q_a = 0{\cdot}24\,T_o$. Therefore, the heat-balance equation for each kilogram of air passing through the system can be written as

$$q_{in} = q_v + q_{vo} + q_a + q_L$$

where q_L is the heat loss of the plant to the surroundings. By means of these relations, the quantity x of water evaporated per kg of air can be determined as

$$x = [0{\cdot}24\,(T_i - T_o) - q_L]/(595 + 0{\cdot}46\,T_o) \quad [\text{kg}_{water}/\text{kg}_{air}]$$

This equation shows that, for very small values of q_L, the evaporation is proportional to the temperature drop $(T_i - T_o)$. For given values of temperature and air flow, it is thus possible to calculate the evaporation fairly accurately.

The heating efficiency η_h of a spray dryer can be defined as the ratio of the heat actually used for evaporation to the heat supplied, so that

$$\eta_h = [0{\cdot}24\,(T_i - T_o) - q_L]/0{\cdot}24\,(T_i - t)$$

or

$$\eta_h = (T_i - T_o - T_L)/(T_i - t)$$

with $T_L = q_L/0{\cdot}24$. The value of the equivalent temperature loss T_L varies with the design and size of the plant used. For a well designed and well insulated plant, its value is between 5 and 20° C. For a small laboratory unit with a drying chamber of less than 1 m diameter (giving a large surface area relatively to the volume), the value of T_L may be as high as 30-50° C.

If the ingoing air is heated to n degrees in a heat exchanger, the heating efficiency becomes

$$\eta_h = (T_i - T_o - T_L)/[T_i - (t + n)].$$

The amount of heat Q required for the evaporation of one kilogram of water is obtained by multiplying the amount of air $1/x$ needed per kg of water by the heat necessary for heating this air to inlet air temperature $(0{\cdot}24\,(T_i - t)$ cal/kg$_{air})$:—

$$Q = 0{\cdot}24\,(T_i - t)/x \quad [\text{cal/kg}_{water}]$$

The above considerations are approximate only. The moisture content of the ingoing air should be taken into account under extreme climatic conditions or if combustion gases from air heaters fired with oil or gas (e.g., methane) are employed. If the product to be spray-dried is hot when entering the system and has to give off only a fairly small amount of water in the drying process (as in soap drying), the heat entering with the feed to the atomiser, and the heat leaving the system with the dried product, should also be considered. Apart from depreciation, heat consumption represents about 70-80 per cent of the running costs of a drying plant.

The power required to take the drying air through the dryer is given by

$$H = L\,\Delta p/(3600 \times 75\,\eta_{ma}) \quad [\text{hp}]$$

where L = amount of air used [m³/hr], Δp = total resistance of the system, expressed as a pressure difference [mm water column], and η_{ma} = mechanical and aerodynamic efficiency of the ventilating system. To this should be added the power consumption of the atomising device and auxiliary equipment (rotary valves, etc.).

SPRAY-DRYING EQUIPMENT

A spray-drying plant comprises ventilators, air heaters, a drying chamber, an air disperser (introducing the dry air), an atomising device for the substance to be dried, and powder separators.

Ventilators: These should have a high efficiency (not less than 67 per cent) and should be of robust construction, capable of operating even if powder deposits occur on the vanes. Ventilators handling heated air require adequate bearing cooling. Centrifugal fans with backward curved blades are usually provided, but axial fans are also being employed to an increasing extent.

Air filters: Although purified drying air is not usually necessary for technical products (tannins, soap, etc.), air filters are employed for the drying of foodstuffs, fine chemicals and pharmaceutical products.

Air heaters: Ordinary steam air heaters are frequently used to heat the drying air. In order to obtain maximum economy in power, plant size, and cost, it is necessary to have as high as possible a steam pressure at the heat exchanger. This gives a high inlet air temperature T_i and, hence, more water can be evaporated per kg of air. However, high steam temperatures and velocities increase the risk of erosion and corrosion. It is thus important for safe operation that the steam should contain no free oxygen or carbon dioxide (the *pH* value must be above 8). For many technical products, tannins, blood, chemicals, soap, non-soap

detergents, etc., it is advisable to use a direct oil- or gas-fired heater, with which any required temperature can easily be reached. A gas- or oil-fired heat exchanger should be used if it is not permissible for the combustion gases to be blended into the drying air and more high-pressure steam is not available. This type of heat exchanger, however, is rather expensive owing to its large surfaces for air-to-air transfer and the special temperature-resistant steels used in its construction.

Drying chamber: Most drying chambers are cylindrical having a conical bottom portion down which the product can slide, or a flat bottom section which requires a device for the removal of the dry product. Some long narrow chambers with a Vee-shaped bottom have also been designed. Certain manufacturers use scrapers, chains, or "air brooms," to prevent powder accumulation on the chamber surfaces. The use of such devices generally indicates that the drying chamber is undersize. In small drying chambers, an after-drying takes place on the chamber walls ; this is not, therefore, a true spray-drying process, in which evaporation occurs only while the particles are suspended in air.

Air separators: The separation of the dried particles from the outgoing air was previously obtained by means of bag filters, but most new spray dryers now use cyclones for this purpose. Although bag filters have a low aerodynamic resistance and give a good separation of powder and air, they are apt to block up, even when shakers are used ; they also tear occasionally and do not stand up very well to the heat of the exhaust air, so that maintenance costs are generally fairly high.

Cyclones are particularly suitable for handling spray-dried powders, but the type, size and number of cyclones to be employed depend on the application. In the author's opinion, the use of multi-cyclone batteries, consisting of perhaps hundreds of small cyclone units, is not suitable for spray-drying. The air-flow through them is less streamlined than in a smaller number of larger units, and cleaning becomes somewhat laborious. Cyclones should require practically no attention and be easily accessible.

Most of the power consumption of a spray dryer is taken up by the cyclones. The resistance through a cyclone is proportional to L^2/T, L being the amount of air passing through [m³/hr] and T the absolute temperature [°K]. The air flow can be determined as

$$L = kD^2 \sqrt{\Delta p\, T} \quad [\mathrm{m^3/hr}]$$

or

$$L^* = 353\, kD^2 \sqrt{\Delta p/T} \quad [\mathrm{kg/hr}]$$

where p = pressure drop [mm water], k = a constant, and D = cyclone diameter or other representative linear dimension. The equation for L^* is obtained by multiplying L by $1{\cdot}293 \times 273/T$, where 1·293 [kg/m³] is the specific weight of air.

Atomiser: The atomiser and the air disperser have the greatest influence on the performance of the entire plant. Atomisation is obtained by means of a pressure nozzle, a two-fluid nozzle, or a rotary atomiser.

The pressure nozzle operates at a high pressure (often up to 200-300 atm) and sprays the liquid in the form of a mist with a swirling motion. It is simple in design and can produce, from milk, for instance, a heavy powder with a low content of occluded air. The pressure nozzle, however, requires a homogenous feed and is not suitable for viscous fluids. For preconcentrated whole milk, the solids content should not exceed 40 per cent. Tungsten carbide or stellited orifice pieces are used to avoid erosion.

In the two-fluid nozzle, a secondary stream of compressed air or steam is used to atomise the liquid into droplets and to give a swirling motion. This type of nozzle can handle viscous fluids, as well as slurries with solid particles, such as Glauber salts and phosphates. However, the particle-size distribution is not very uniform, except in very fine powders. The size distribution is appreciably affected by variations in the amount of feed, in both types of nozzles considered.

The rotary atomiser operates with a rapidly rotating disc or vane wheel, which is driven through gears by a steam, air or oil turbine, or by a high-speed motor. The material is fed near the wheel centre, and reaches peripheral speeds which are frequently above 150-170 m/sec. The liquid is released at a high pressure and is also dispersed by the air streams occurring as a result of the relative airspeed. Some designs have wheels of 20-25 cm with 20-30 vanes. The rotary atomiser, therefore, combines the effects of the two nozzles previously described and has a considerable capacity. It is mechanically more complicated and absorbs somewhat more power than the nozzle systems. The particle-size distribution is hardly affected by even large variations in the amount of feed.

Air dispersers: The design of air dispersers is based on practical experience. An analytical treatment would have to take account not only of the air currents in the drying system, but also of the contraction of the drying air as it gives off its heat and the currents caused by the nozzles or the rotary atomiser. There must be no scorching of dry or semi-dry particles through accidental contact with fresh hot air.

Dispersers are either of the counter-flow or the parallel flow type. In counter-flow systems, the atomiser is situated below the air outlet at the top of the drying chamber, while the hot air inlet is near the bottom of the chamber. Owing to ascending air currents and eddies, semi-dry particles frequently collide and agglomerate with others. This results in the formation of loose lumps at the bottom of the dryer, and semi-moist particle deposits on the walls. These spraying chambers are often towers of up to 10 m diameter and 20-25 m high. They are generally placed in the open and are often used for detergents, where coarse particles are wanted.

Air dispersers of the parallel flow type are by far the most widely employed. The air disperser and the atomiser are placed close together and the moist product leaves the nozzle or rotary atomiser at a very high speed, which is soon reduced to that of the surrounding air stream. In a first, comparatively small, zone in the drying chamber, the wet particles evaporate extremely rapidly at a high temperature. The drying air gives off most of its heat in this zone, which can be approximately determined by observing the atomisation and evaporation of pure water droplets in the vicinity of the atomiser. In the second zone, almost stationary conditions prevail ; the particles have such a low moisture content that the rate of diffusion to the surface of the particle determines the rate of evaporation. The temperature of the particles gradually converges to that of the air so that at the outlet position the evaporation has practically ceased.

Particle size: A minimum variation in particle size is an important requirement. If the spray from the atomiser contains particles of widely different sizes, the small droplets may dry out entirely and become overheated, while the large particles may leave the first zone with still enough moisture in them to adhere to the walls of the drying chamber. The drying process is easier to carry out with small-size than with large-size particles. A quantity of 1 kg of water, atomised to droplets of 200 μ, has a total surface of 30 m², whereas its surface is 600 m² if the particle size is reduced to 10 μ. Coarse droplets take longer to evaporate and therefore require a larger drying chamber than small droplets. In the case of milk powder, the coarse powder has less surface exposed to the air, and therefore has better keeping qualities, since deterioration of the whole milk powder is mainly due to oxidation. From a sales point of view, a coarse powder obtained from a slurry of synthetic detergent generally has a more pleasing appearance than a very fine powder.

The conditions are complicated by the fact that most spray-dried products form hollow particles. The author's opinion is that air is introduced into the droplets during atomisation, particularly with a rotary atomiser.

During the early stages of the drying, a crust is formed, which may be overheated for a brief period, after which explosive evaporation occurs, which blows up the semi-solid surface of the particle. The hollowness of particles can be altered within limits by altering the rotary atomiser design or varying the inlet air temperature, but the conditions may differ according to the product considered.

General remarks: Spray drying is a very rapid drying process. Most of the moisture is evaporated in less than a second, and the particle is in the dryer for less than one minute. The drying takes place while the material is suspended in air, without contact with a heated surface. The process takes place at a fairly low temperature. Thus, egg white, which coagulates at 60° C, can be spray-dried with an inlet air temperature of 180° C and then gives a perfectly soluble powder. Enzyme solutions and even live yeast cells may be spray-dried, but with these a slower rate of drying gives the best results.

The water vapour developed from a droplet during evaporation has a volume about 1000 times that of the droplet, which is therefore surrounded by a sphere of vapour approximately 10 times its diameter. This vapour prevents oxidation of the droplet. For instance, ferrous sulphate can be spray-dried and its salt will contain no ferric iron if the sulphate is taken from a closed feed tank with an oxygen-free atmosphere at the surface of the solution. Another easily oxidisable substance is ascorbic acid, which can also be spray-dried without deterioration either as a constituent of fruit or vegetable pulps, or in its pure state. Thus, there is not much point in drying in an atmosphere of an inert gas, provided that the dried product has no tendency to oxidise. This is, however, the case with many substances (e.g., fish meal) having a high content of fats and unsaturated fatty acids, and such products may actually be dangerous.

TYPICAL APPLICATIONS

As a first example, we shall consider a plant for human blood serum, working at an inlet air temperature of 75° C and an outlet temperature of 48° C. Using the formulae previously given, and assuming $T_L = 9°$ C ($q_L = 2{\cdot}2$), it is found that 1 kg of air evaporates only about 7 grams of water. The heating efficiency is only about 28 per cent, but this is of minor importance in this case, where sterility and perfect solubility of the product are the main requirements. The efficiency is certainly higher than that obtained with a freeze dryer.

A milk-drying plant will be taken as a second example. It is required to treat, for instance, 5000 kg of whole milk per hour, and the solids content is about 12 per cent, or 600 kg. A preconcentration of 50 per cent, giving 1200 kg of feed for the atomiser, is first obtained by evaporating 3800 kg of water in an evaporator plant, and this requires about 1800 kg of steam.

Assuming that the spray dryer works with steam at 12 kg/cm² and 190° C, its inlet air can be heated to $T_i = 175°$ C. If $T_0 = 90°$ C, and $t = 10°$ C, and $T_L = 5°$ C, the formulae give an evaporation $x = 30$ gr/kg, $\eta_h = 48$ per cent, and a total heat consumption of $600 \times 1320 = 792{,}000$ kcal/hr for the entire plant. The steam enters the air heater with a heat value of 663 cal/kg and leaves it as water at a temperature of 70° C, thus giving up 593 cal/kg. Therefore, 792,000/593 = 1335 kg/hr of steam is required for the entire evaporation process, of which 792,000/663 = 1200 kg/hr are used for air heating. The quantity of drying air required is 600/0·03 = 20,000 kg/hr. Taking 200 mm water as the total air resistance of the system and assuming an overall efficiency of 55 per cent for the fans, belt drives and motors, the plant will require 27 hp for the air, plus some 12 hp for the atomiser and 8 hp for auxiliary equipment, giving a total of 47 hp.

By means of a heat recuperator in which the outlet air is used to heat the inlet air from 10-45° C, the efficiency is raised to 61 per cent, with a heat consumption reduced to 624,000 kcal/hr or 1050 kg of steam per hour (a saving of 21 per cent). The 1800 kg/hr of steam for the evaporator plant is the same in both cases.

The importance of having a highly concentrated feed for the spray dryer can be appreciated by considering the case of milk preconcentrated to 33·3 per cent solids only. The overall steam consumption is increased by about 25 per cent, the power absorbed by the dryer is practically doubled, and the initial cost and size of the plant would also be greater.

The 8 hp previously mentioned for auxiliary equipment is required by the pneumatic and cooling devices for the powder. After leaving the drying chamber and the cyclones, the powder is taken through rotary valves into a narrower duct, through which filtered cold air flows at a fairly high speed. The duct leads to a separate cyclone placed above a hopper in the store-room. The powder can then immediately be bagged or put into tins. In freshly prepared milk powder, the fat and the sugar exist in an undercooled unstable form. Crystallisation takes place after a short while and causes a rise in temperature, so that if no cooling is provided, an otherwise perfect milk powder may be spoiled if packed when hot. Pneumatic conveying systems are used for many products and are an integral part of large modern spray-drying plants.

As a last example we shall consider a dryer for tannin extract powder from a 50 per cent extract. Assuming that it is required to produce one ton of powder per hour with 5 per cent moisture, this will require 1900 kg/hr of concentrate and the evaporation of 900 kg/hr of water. The plant will be assumed to be heated by a direct oil-fired heater, from which the combustion gases are blended with air to obtain a suitable air inlet temperature, using also a heat recuperator. If $T_i = 250°$ C, $T_0 = 105°$ C, $q_L = 5$, and $t + n = 50$, it is found that $x = 52$ gr of water per kg of air, $\eta_h = 70$ per cent, and $q = 830{,}000$ kcal/hr. With oil having a calorific value of 10,000 cal/kg, the oil consumption is 83 kg. The total amount of air is 19,200 kg/hr, and the total power consumption 50 hp, calculated as in the previous example. Taking account of the cost of fuel oil and electricity, it is seen that spray drying can be extremely economical, particularly with comparatively large plants.

During the discussion of this paper which was presented to the Hague Section for Chemical Engineering, it was mentioned that scorching due to powder deposition in the air disperser could be avoided by various means, such as (a) insulation, (b) water cooling, and (c) air supplied through fine holes in the walls at critical positions. Recirculation of spent air is generally not advisable, since fines are recirculated with it and their scorching cannot be avoided. Heat-sensitive products, moreover, are then subjected to excessive increases in temperature. To recuperate the heat content of spent air, use should be made of heat exchangers. It was pointed out that direct-fired air heaters may give SO_2 in the drying air. When pressure nozzles are used, the dry matter content may reach 47 per cent with full-cream condensed milk (at 180 kg/cm²). For high feed concentrations, rotating wheels give good results (parallel flow operation), and two-fluid nozzles are suitable for counter-flow operation. Atomisation with flat discs gives uniform particle size at a very low feed rate, whereas the commercially available types of vane wheels show some variation in particle diameter.

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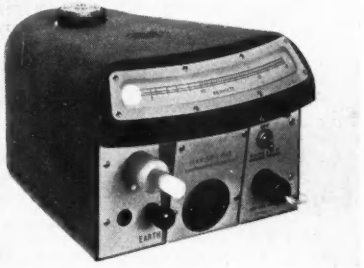
New Materials, Processes and Equipment

ELECTROSTATIC VOLTMETER

The " Scalamp " electrostatic voltmeter was developed by W. G. Pye & Co. Ltd., Cambridge, primarily for use in testing E.H.T. for cathode-ray tubes used in television receivers and cameras, but its compactness, portability, ease of operation, and accuracy make it suitable for a very wide range of applications.

A specially designed vane is held in the proximity of a well-insulated electrode by a taut-suspension of the galvanometer type. The movement is critically damped under all circumstances by a magnet damping device.

The lamphouse is integral with the front panel. The inside face of the lamphouse carries the optical system. The external face comprises a removable panel upon which the 4-volt bulb is mounted. The bulb can be changed easily and quickly without disturbing any other components of the instrument.



The standard " Scalamp " electrostatic voltmeter is fitted with a transformer for use on a.c. mains, 200-250 V. Connection is made via a 2-pin safety plug recessed into the front panel. For portable use or where no mains supply is available, removal of a shorting bar allows the instrument to be operated from a battery. A switch, which is operative on both the mains and battery connection, allows the lamp to be switched on and off as required.

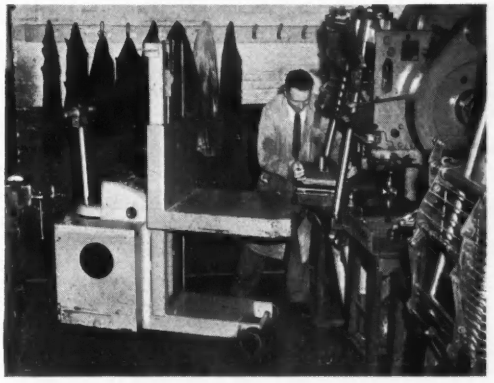
DIE HANDLER

The high overhead charges on all modern machine tools as well as power presses, die casting and moulding machines render it essential to reduce to a minimum the unproductive change-over periods from one job to the next. The recently introduced Lansing Bagnall electrically operated die-handler truck has been developed to allow very large reductions in set-up times.

Dies, moulds and similar gear may be stored in a number of different places and this truck has been rendered sufficiently versatile to enable it to be used in virtually any practical location.

To take a die to the machine, the platform of the truck is raised to the level of the rack holding the die and the die is slid smoothly from the rack to the platform, which can then be lowered to its bottom position to give the maximum stability to the machine during transport. The die-handler is pedestrian-controlled and the entire drive unit, consisting of the driving handle, motor, control box and gear box, is mounted on a double ball track, bolted to the main frame. The driving unit follows the control handle and steers automatically through an arc of 200 deg.

The driving motor is a variable-speed, shunt-wound, d.c. interpole traction motor rated 2½ hp and powered



by 48-volt lead-acid batteries of 99 Ah capacity. The driving controls are all conveniently located in the handle head and consist of a twist grip speed control and a preselective direction switch. A master key-switch and circuit breaker (with automatic low-voltage release when the battery voltage falls too low, and a hand-reset thermal trip to prevent overloading of the motor) are resiliently mounted on a panel above the motor. The speed is continuously variable from 0 to 4 mph.

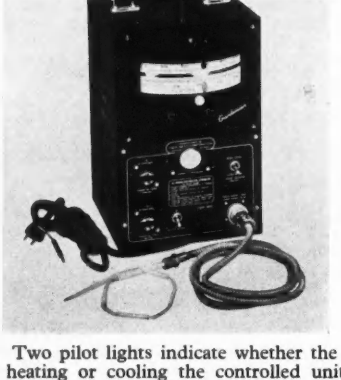
The power lift comprises a hydraulic pump driven by a separate electric motor actuating a heavy-duty single extension hydraulic jack. The same simple push-button control, which actuates the hydraulic lift via a solenoid switch, also incorporates a screw release valve to permit the lowering speed to be controlled at will. A pressure relief valve is provided to prevent overloading, whilst a limit switch ensures automatic cut-out at the end of the lift.

The 27 in. by 30 in. platform can take loads up to 1 ton. This is more than adequate for the vast majority of applications, though special designs for all types of tools and dies can be prepared by the manufacturers of this truck (Lansing Bagnall Ltd., Kingsclere Road, Basingstoke, Hampshire, England) and heavier capacity models, with alternative platform sizes are available.

PORTABLE TEMPERATURE CONTROLLER

Precision control is accomplished by plugging this instrument into a wall outlet and plugging the unit to be controlled into the instrument. Then, by inserting the instrument thermocouple into an oven, bath, thermocouple well, etc., the true temperature will be indicated by the upper pointer and may be controlled at any desired point by setting the lower pointer to the correct scale position by means of an external setting knob. Two power outlets provide an unusual degree of versatility to this instrument by enabling it to control blowers, fans, agitators, etc. All models have a dual scale range of 50° to 500° F, iron-constantan, and 0° to 2000° F chromel-alumel, with a selector switch to operate the instrument on one range or the other. Two six-foot thermocouples, one iron-constantan and the other chromel-alumel, are standard equipment.

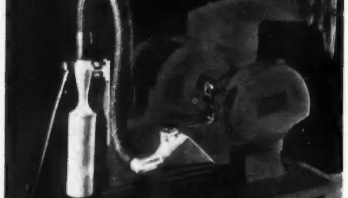
In this instrument, manufactured by Taco West Corporation, Chicago, magnetic amplification replaces the usual vacuum tubes, thus eliminating service interruption due to tube failure and assuring instantaneous



starting. Two pilot lights indicate whether the instrument is heating or cooling the controlled unit. The accurate telephone-type relay of the instrument is supplemented by an integral contactor of 1700 W capacity, thus permitting the use of these instruments directly on most load circuits without an external contactor.

INDIVIDUAL DUST COLLECTING UNITS

For use on surface grinders and other grinding machines where grinding dust must be removed, the Vulcan Tool Co. of Dayton, Ohio, have developed inexpensive, compact units, with no moving parts, operated from the existing air supply. These units are installed in a few minutes, and eliminate the need for costly centrally located dust collecting systems.



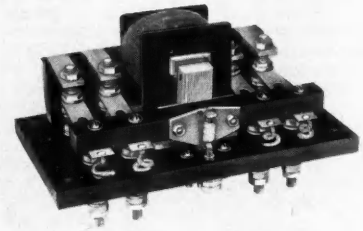
The units are quickly cleaned, and require no refills. Positive location of dust cup is ensured by mounting on the grinding wheel guard or close to the grinding wheel. This permits constant contact with dust as the wheel is moved up or down. The collector element is mounted on the side of the machine. A simple needle valve operates the units, and can be shut off when the machine is not in use.

HEAVY-DUTY RELAY

This new relay, manufactured by Electro Methods Ltd., 220 The Vale, London, N.W.11, falls suitably between the general type commercial relay switching up to 5 A, and the higher rated contactor types.

The U-shaped frame and armature are made of high-grade silicon-iron laminations. The armature is self-aligning and is provided with a fixed air-gap to prevent "sticking." It carries the contact-blades on a simple hinged assembly which confers a high anti-G property and the ability to withstand a relatively high degree of vibration.

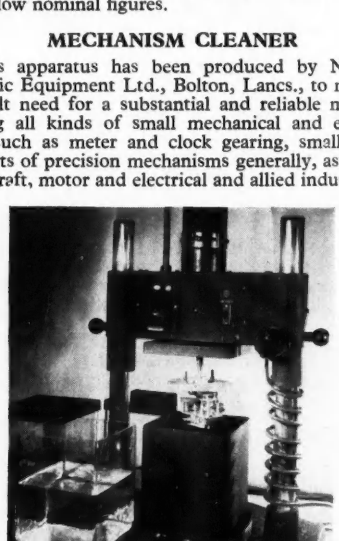
The contacts are made of fine silver which ensures long service life and low contact resistance. In operation, the moving contacts undergo a wiping action with both upper and lower fixed contacts, a feature which promotes high pressure and continuity even at low voltage on small loads. The fixed contacts are adjustable to compensate for wear and all contacts are easily replaceable.



Coils are available for all voltages up to 250-V d.c. or 440-V a.c. They are fully impregnated and baked and will operate on voltages 10 per cent above or 15 per cent below nominal figures.

MECHANISM CLEANER

This apparatus has been produced by Northern Scientific Equipment Ltd., Bolton, Lancs., to meet the wide-felt need for a substantial and reliable means of cleaning all kinds of small mechanical and electrical parts, such as meter and clock gearing, small screws and parts of precision mechanisms generally, as used in the aircraft, motor and electrical and allied industries.



The cleaning basket, the speed of which is 120 rpm when immersed in the cleansing solution, is 8 in. in diameter and therefore capable of holding moderately large articles; removable subdivisions enable it also to be used for the cleansing of small parts. The basket is removable, and clamps are provided to enable a complete clockwork or other mechanism to be held in position and cleaned as a unit.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

INTERNAL COMBUSTION ENGINES

Flame Photographs of Auto-Ignition Induced by Combustion Chamber Deposits

By L. L. WITHROW and F. W. BOWDITCH. (From *SAE Quarterly Transactions, U.S.A.*, Vol. 6, No. 4, October, 1952, pp. 725-752, 30 illustrations.)

DESPITE the fact that the information contained herein permits no definite conclusions regarding all cases of auto-ignition, it is possible to make a number of general observations which bear on the deposit problem. The principal purpose of the paper is to present clearly and accurately some of the existing evidence on the relationship between engine deposits and their effects on combustion.

One of the most important characteristics of the auto-ignition process as observed in flame pictures is the fact that ignition is induced by particles of incandescent deposit moving in the gaseous mixture as well as by particles attached to the combustion chamber walls. Obviously, if the deposits never purged themselves, the combustion chamber would soon fill up with solid material and require mechanical attention. Thus, it is apparent that in the process of eliminating one problem, the deposit removal introduces another in the form of auto-ignition.

Since knock, pre-ignition and other forms of auto-ignition were recognised as problems associated with the operation of automobiles prior to the general use of leaded petrol, it cannot be concluded that the only cause of auto-ignition is the presence in the combustion chamber of decomposition products of leaded fuels. The reason for this is that traces of chemical substances found in the atmosphere are capable both of lowering the ignition temperatures of carbon, and of accelerating the chemical reactions between carbonaceous deposits and oxygen in the air. A wide variety of chemical compounds may therefore be responsible for the tendency for deposits containing no lead to purge themselves from the combustion chamber and in so doing to produce incandescent particles or surface areas capable of inducing auto-ignition.

Since the general distortion of the inflammation process depends on the outcome of the race between the time of occurrence of the ignition spark and the beginning of inflammation induced by combustion chamber deposits, it is indeed fortunate that the deposits kindle the mixture between 20 deg. before T.D.C. and T.D.C. in the majority of the cases. In most instances, in fact, the deposits initiate normal inflammation after the ignition spark has occurred and the charge is partially burned. This general observation, together with the apparent fact that the deposits become more effective in igniting the mixture as the pressure and temperature of the non-inflamed charge increase, leads to three interesting deductions :—

(1) It is possible for the deposits to be igniting the fuel-air mixture in advance of the normal flame fronts and still not cause the engine or the automobile to continue running after ignition is turned off. Auto-ignition can only occur when the deposits or the wall surfaces are so active that the mixture is ignited at the pressures and temperatures that develop at or near T.D.C. under the degree of compression developed by the piston alone.

(2) It is obvious that the effects of deposits on the general character of the inflammation process may be alleviated by advancing the spark. But, as is well known, this simply amplifies the knock problem. Finally, it is also obvious that under certain operating conditions, combustion-chamber deposits may be distorting the nature of the inflammation process in non-knocking explosions as well as in knocking ones, and thereby decreasing engine efficiency and reducing fuel economy.

(3) The data contained herein indicate that auto-ignition induced by combustion chamber deposits may depreciate the mechanical octane numbers which are designed into some combustion chambers. The depreciation may be expected to be most pronounced in those chamber designs which require accurate control of the time and place of ignition as well as the direction of flame propagation once it is initiated. In view of these many opposing influences, customer experience must finally determine the chamber design which offers the best compromise.

LUBRICANTS AND LUBRICATION

Lubrication in Deep Drawing

By E. I. ISATSHENKOV. (From *Vestnik Mashinostroyenya Russia*, No. 10, 1951, pp. 60-68, 10 illustrations.)

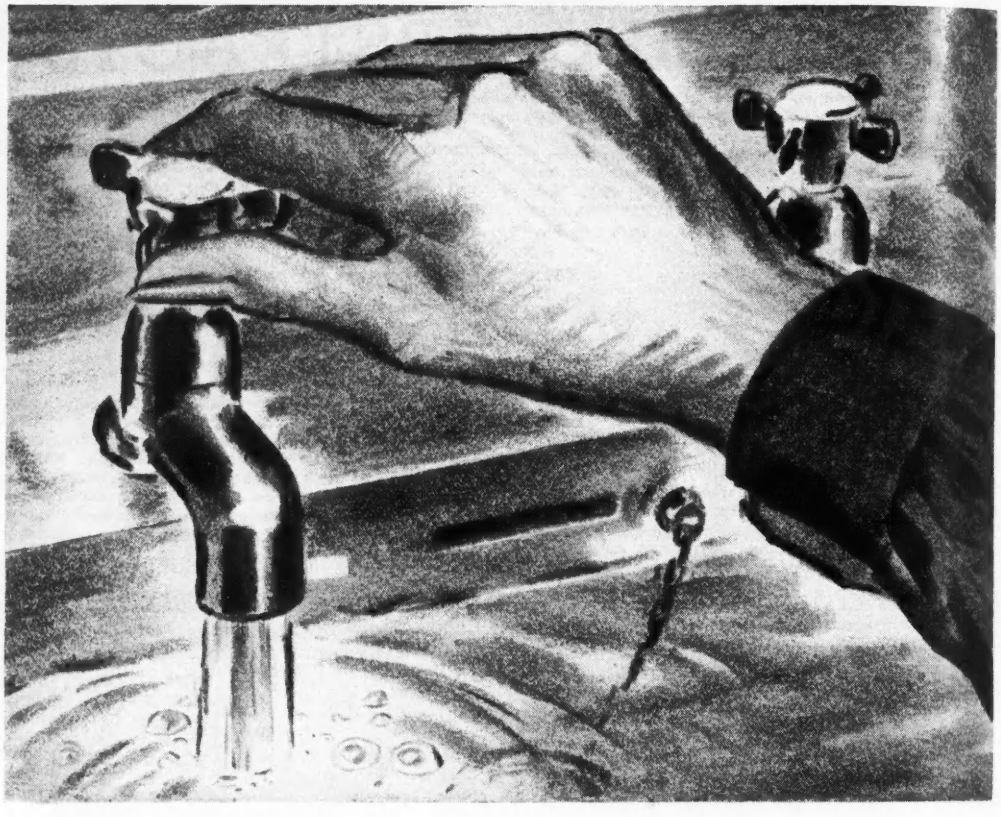
THE mechanism of lubricating action in deep drawing is not fully understood and a rational choice of lubricating medium is difficult. In practice, compositions of up to 6 or 7 constituents are used without giving full satisfaction. The author's investigations show that the mechanism of boundary lubrication does not fully explain the lubricating action in deep drawing, and the application of the hydrodynamic theory must be considered.

A large variety of lubricating materials were graded by their effect on the drawing pressure. This classification revealed several influences which cannot be explained by the boundary lubrication theory. Lubricants having the same viscosity but different chemical composition are almost identical in their effect on the drawing pressure. On the other hand, there is an optimum viscosity which gives the lowest drawing pressure, and provided this viscosity is maintained, such cheap lubricants as paraffin wax and soap give the same effect as animal and vegetable oils of high surface activity.

An important factor in the choice of lubricant is the speed of deformation. The author's tests included a large range of velocities and show that, as a velocity of 0·05 mm/sec, the optimum viscosity of the lubricant is one million poises ; in other words, it constitutes an almost solid plastic mass. At a speed of 300 m/sec, the optimum viscosity is reduced to 0·02 poises, which corresponds to the consistency of a thin liquid.

A third factor of importance in the choice of lubricant is the specific pressure between the blank and the die. The optimum viscosity increases with an increase in the pressure. Other factors which determine the effectiveness of a lubricant are the relative depth of drawing and the temperature of the blank and the die.

The conclusion from these investigations is that the determination of the optimum viscosity by practical tests is possible and worthwhile in each concrete case. On the other hand, the chemical nature of the blank and of the lubricant have only a secondary effect.



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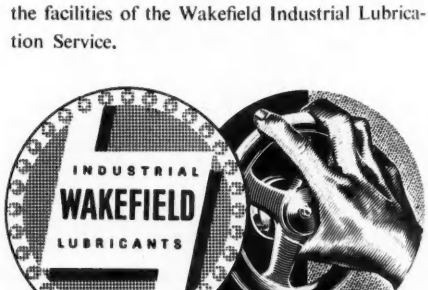

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STEAM POWER PLANTS

The Optimum Boiler Water: a Continuing Problem in Chemical Engineering Design

By E. P. PARTRIDGE. (From Paper No. 33, Group III, Section 36, presented at the *4th International Congress of Industrial Heating*, Paris, 1952, 10 pages, 7 illustrations.)

A STANDARD composition of boiler water is impractical because boilers are not alike. Even those which appear similar may differ in the complex relationship between heat transfer, fluid flow, temperature and stress.

In extreme cases, the phenomenon of film boiling—the development of a continuous blanket of steam—may occur on the surfaces of vertical wall tubes. Inevitably, on every surface where boiling takes place, there is a tendency for dissolved substances to concentrate. Anything which interferes with rinsing of such surfaces may allow excessive concentration with resultant attack on the steel.

Because chemicals used for conditioning may produce bad as well as good effects, the concept of "pure" water in boilers has proved attractive. However, steel is not protected as well from corrosion at the pH of 8·5-9·0 characteristic of operation on "pure" water or the somewhat higher pH produced by the "captive alkalinity" of phosphate as it is by the presence of a low concentration of free sodium hydroxide. Where local stress exists in the steel, rapid attack by "pure" water may occur. Dissolved oxygen, which has been blamed for this type of damage, does not appear to be the essential factor.

Experiences in a number of plants are cited, on the one hand with film boiling and attack by concentrating film, and on the other hand with stress corrosion by water lacking free sodium hydroxide. It is concluded that the boiler water must be designed to meet the special conditions inherent in the operation of the boiler.

STRESS ANALYSIS

Residual Stresses in High-Speed Turning

By P. E. DYATCHENKO and A. P. DOBYTCHINA. (From *Vestnik Mashinostroyenya*, *Russia*, No. 10, 1951, pp. 36-42, 8 illustrations.)

FATIGUE failures originate in a zone of maximum tension stresses. A suitable choice of conditions for surface machining can result in a distribution of residual compression stresses at and near the surface which will lower the tension stresses under load. An increase of fatigue strength can therefore be obtained by machining without a separate operation being carried out for the sole purpose of introducing residual compression stresses into the surface region.

Residual stresses in machining are the result of the action of two factors, namely, the stresses set up during the machining operation and the heat generated by this operation.

Under the action of the cutting forces, tension stresses arise in the surface layer of a depth determined by the elastic properties of the material. Simultaneously, this layer is pressed onto the material below to a degree which causes work-hardening. When the forces which set up the stresses are removed after the passage of the cutting edge, the cold work performed in a state of tangential tension does not allow the restoration of the initial state, and part of the surface tension is frozen into a residual tension stress. The combination of increased hardness and brittleness with a locked-up tension stress can have a most varied effect on fatigue strength. On the other hand, the combination of surface hardening with a compressive residual stress invariably increases fatigue strength.

The heat liberated in cutting can either increase the tension stress or decrease it and even convert it into a compression stress. The latter phenomenon is analogous to the compressive surface stress set up in the induction hardening of steel components, and is explained by the same sequence of thermal events and metallurgical transformations. In practice, the final result is determined by the conditions of the cutting operation. The authors have investigated experimentally the effect of cutting conditions on residual stresses. Residual stresses were revealed by the deformation of a slotted ring. The distribution of residual stresses was established by periodic measurements during the removal of the surface layer in an electro-polishing bath.

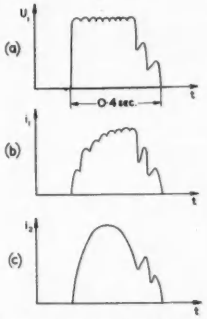
The combination of high cutting speed with a negative rake of the cutting edge ensures the setting-up of residual compressive stresses. The optimum negative rake angle is 30 deg. The cutting speeds required for this are above 300 and preferably 500 m/min. The experiments were carried out on medium carbon steels, and the authors found that high-speed machining with negative rake not only gives the desired physical result but also yields a very smooth surface similar to that obtained by grinding.

WELDING

The Utilisation of Impulses from a Low-frequency Source of Current for the Spot Welding of Light Alloys

By A. S. GELMAN. (From *Avtogenoye Dyelo*, *Russia*, No. 4, 1952, pp. 6-7, 1 illustration.)

TESTS with impulses from low-frequency sources were carried out in the spot welding of dural sheet of 4 and 5 mm thickness. The figure shows the time history of the voltage and the primary and secondary currents of the spot welding machine. The welding was carried out with impulses of 0·4 second duration, and under an electrode pressure of 800 kg.



These experiments lead to the following conclusions:

(a) The three-phase, low-frequency spot welding machine of 200 kVA gives an impulse strong enough to weld two dural sheets of 5 mm thickness.

(b) At a spot distance of 50 mm (with 4 mm thickness) and 70 mm (with 5 mm thickness), there is no noticeable influence due to the distribution of current to two welding points.

Impulses from sources of low frequency for the spot welding of light alloys have fundamental advantages:

(1) The gradual increase of the welding current improves the stability of the electrodes and reduces the risk of damage to the surface of the welded parts.

(2) The gradual increase of current in the primary circuit of the welding transformer, a uniform loading of the three-phase network, and a high power factor owing to the small inductive resistance at low frequency, all combine to achieve the high power efficiency of this machine.

(3) The possibility of limiting the impulse of welding current to a definite value in the primary circuit facilitates the achievement of uniformity in the welds.

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NEWS OF THE MONTH

PERSONAL

Mr. R. L. Batley, A.M.I.Mech.E., chief generation engineer (operations), Merseyside and North Wales Generation Division, British Electricity Authority, has been appointed controller, Midlands Division, in succession to **Mr. F. W. Lawton, M.I.E.E., M.I.Mech.E.,** who is retiring at the end of this year.

Mr. J. Birckbeck has been appointed production manager of Brynmawr Rubber Ltd.

Mr. G. F. Brown, secretary, has been appointed director and secretary, and **Mr. B. E. J. Hodson,** general works manager, works director, of Garringtons Ltd., Bromsgrove, Worcestershire.

Mr. Harold Burke, M.I.Mech.E., has been appointed joint managing director of Concentric Manufacturing Co. Ltd., Tyburn Road, Birmingham, and a director of its subsidiary companies, Rowmill Metals Ltd. and T. Miller Ltd.

Mr. H. G. Carter, A.C.A., secretary of Lancashire Dynamo Holdings Ltd., has been appointed to the Board of the Company.

Mr. A. S. C. Chattey has been appointed managing director of A.C.V. Sales Ltd.

Lt.-Commander G. Dennison is joining Airspeed Precision (London) Ltd., 22 Bruton Street, London W.1, as liaison officer.

Mr. R. F. Earley, B.Sc., A.M.I.C.E., A.M.I.Mun.E., F.G.S., has joined **Mr. Daniel Longden, M.R.San.I., M.I.San.E.,** to form the firm of Longden and Earley, consulting engineers, at 2 Promenade Chambers, Edgware, Middlesex.

Mr. Maurice B. Gavan has been appointed purchasing agent of Reads Ltd., Orrell House, Liverpool 9.

Mr. Ian M. Gillett, general manager, has been appointed managing director and **Mr. Brian H. Dulanty** has been appointed to the Board of Silentbloc Ltd. **Mr. S. Buchan, M.A., B.Sc., Ph.D.(Cantab.), F.R.I.C., F.I.R.I.,** general manager of the Andre Rubber Co. Ltd., has been appointed a director of the Company.

Mr. R. A. Harding has been appointed to the Board of Macrome Ltd., Aldersley, Wolverhampton. Mr. Harding joined the Macrome organisation in 1945, becoming general manager in 1951. He now holds the position of general manager and director.

Mr. D. G. Hawkins has been appointed general manager of the National Gas and Oil Engine Co. Ltd., Ashton-under-Lyne.

Mr. F. C. Hooper has been appointed a director of Ilford Limited, in succession to **Sir Philip Haldin** who has relinquished his position on the Board of the Company.

Mr. A. Robert Jenkins, J.P., A.M.I.Mech.E., President of the Institute of Welding, has accepted an invitation to serve on the Comite de Patronage of the Third International Congress on Electro-Heat, to be held in Paris from May 18 to 23, 1953.

Mr. D. R. Mackie has been appointed to the Board of Monsanto Chemicals Ltd. Mr. Mackie, in addition to his responsibilities as a director, is retaining his present position as general manager of sales. **Mr. A. D. Daysh** is retiring from his position as a director of the Company on January 31st, 1953.

Mr. John MacLean has been re-elected chairman, and **Mr. I. C. MacFarlane,** deputy chairman of the Clyde Navigation Trust.

Mr. F. A. Martin has been elected President of the Sheffield and District Branch of the Institute of British Foundrymen, in succession to **Mr. W. J. Colton.**

Mr. F. Moores, B.Sc.(Eng.), A.M.I.E.E., has been appointed manager of the capacitor department of Johnson & Phillips Ltd., London, S.E.7.

Mr. H. N. Norbury has joined Henry Meadows Ltd. as sales manager for home and overseas sales.

Mr. W. Owen, M.I.Mech.E. has been appointed assistant chief engineer of Saunders-Roe (Anglesey) Ltd., coach division, Beaumaris, Anglesey, N. Wales.

Lt.-Colonel H. Riggall, D.L., J.P., deputy chairman and managing director of Ruston and Hornsby Ltd., Lincoln, has been appointed a Governor of Loughborough College of Technology.

Mr. E. S. Waddington, F.S.E., A.M., (s.a.) I.Mech.E., M.Inst.W., Associate I.E.E., Associate (s.a.) I.E.E., of Philips Electrical Ltd., Century House, Shaftesbury Avenue, London, W.C.2. (Industrial Group) has just been appointed by the Sheet Metal Users' Technical Association as their representative on the British Standards Institution Technical Committee WEE/24-Projection Welding in Mild Steel. Mr. Waddington has also been re-elected vice-chairman of the BEAMA Arc Welding Plant Section.

Mr. A. S. Walker, A.M.I.Mech.E., has been appointed lecturer in the mechanical engineering department of the Woolwich Polytechnic, London, S.E.18.

Mr. J. F. Whitfield, M.I.Mech.E., has been appointed general manager of B. Thornton Ltd., Turnbridge, Huddersfield.

Captain J. J. Youngs, O.B.E., D.Sc., R.D., R.N.R., has been appointed marine superintendent of The New Zealand Shipping Co. Ltd.

MR. P. E. ERIKSON

We announce with deep regret the sudden death of **Mr. P. E. Erikson, M.I.E.E., F.Amer.I.E.E., Member Svenska Teknologforeningen,** a member of the International Standard Electric Corporation, at his home at Malmo, Sweden, at the age of 72.

MR. FRANK GURNEY

We announce with deep regret the death of **Mr. Frank Gurney, M.I.E.E.,** who died on November 27th at a London hospital after a brief illness.

Mr. Gurney, whose appointment as home sales manager was announced recently by Metropolitan-Vickers Electrical Co. Ltd., had been with the Company for over thirty years. He was chairman of the North Midland Centre of the Institution of Electrical Engineers in 1941-42.

BUSINESS NOTES

Thos. Firth & John Brown Ltd., Atlas Works, Sheffield 4, announce that the new address of their London Office is as from December 1st at 11 Hamilton Place, Piccadilly, London, W.1. Tel. No. Grosvenor 8781. Telegraphic Address : Mesmeric Audley London.

Riley Stoker Corporation of Worcester, Massachusetts, and **John Brown & Company Limited** have concluded an Agreement which secures to John Brown a license to manufacture and sell to Riley Stoker Corporation's design components and complete steam generating plant and equipment for use in land power generating stations. Riley Stoker Corporation is one of the leading suppliers of steam generating plant in the United States and is responsible for some of the most economical and powerful installations steaming anywhere in the world ; some of these operate at temperatures and pressures much in advance of current British practice, and Riley Stoker Corporation's experience in the special design and manufacturing techniques which these high temperatures and pressures involve will also be available to John Brown & Company Limited under the Agreement. John Brown's substantial manufacturing resources will make Riley steam generating plant more readily available throughout the world.

Mullard Equipment Limited have recently acquired another factory at Wandsworth in Garratt Lane, London, S.W.18. All engineering development facilities, together with centralised work-

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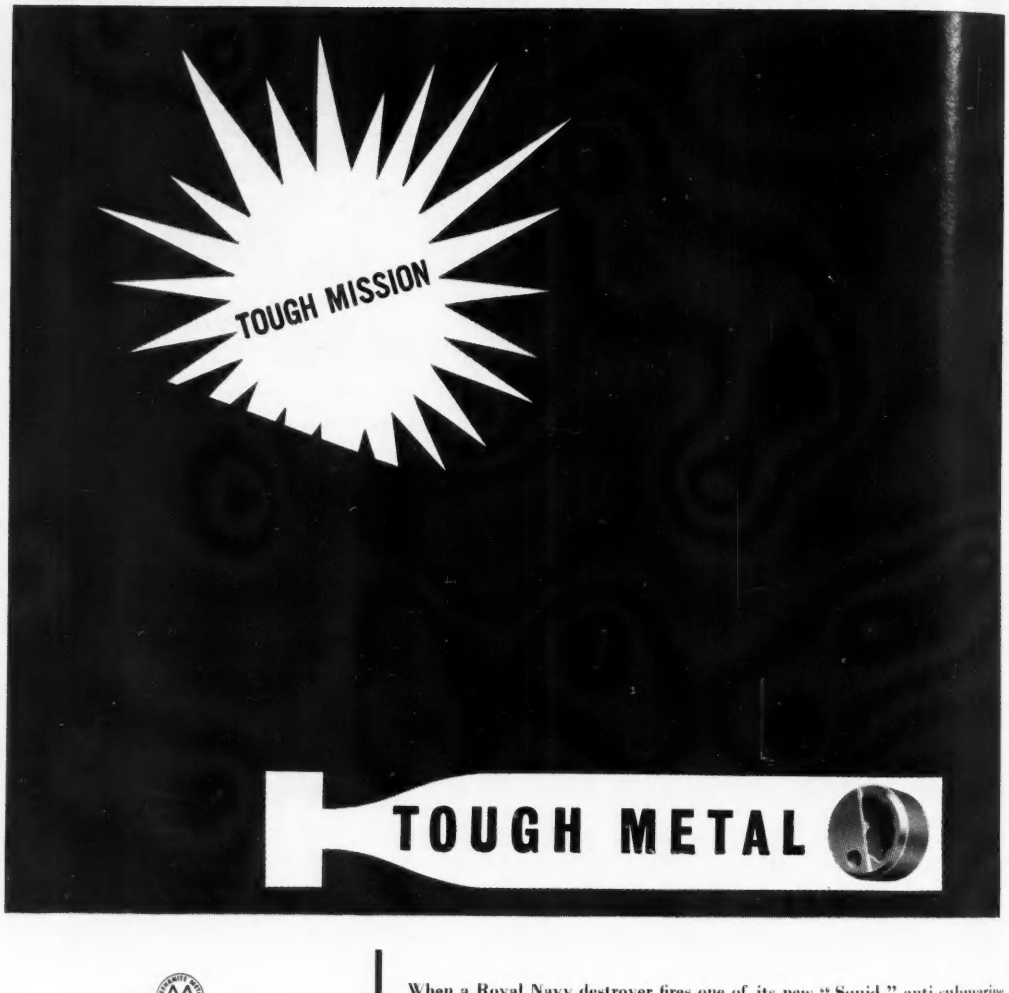

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shop areas, are now being concentrated in the older factory at Brathway Road. At Garratt Lane are housed the main assembly and production lines for all classes of equipment, as well as factory administration and service departments. Research and advanced development will continue to be done at the Mullard Company's Research Laboratories at Salfords, Surrey.

The name of the Firm of **H. H. Cooper & Co. (Verwood) Ltd.** has been changed to **The Gull Enterprise Ltd.,** Engineers, Verwood, Dorset.

Monsanto Chemical Company of St. Louis, U.S.A., announced today the formation of a new jointly-owned French company in association with Compagnies Réunies des Glaces et Verr Speciaux de la France.

The new company, La Société Monsanto-Boussois, S.A., will produce plastic materials, including polystyrene moulding compounds, which will be manufactured under processes owned by Monsanto, and developed by its Plastics Division at Springfield, Mass.

Engineering will start immediately and construction will follow at Wingles, near Lens, the site of an existing glass manufacturing plant owned by the French parent company. Operations will start prior to mid-1953.

The Tudor Accumulator Company Ltd., Dukinfield, Cheshire, announces that the Company's London Office has now been removed to 137 Victoria Street, London, S.W.1. Telephone: Tate Gallery 0307.

The London Office of **Pritchett & Gold and E.P.S. Co. Ltd.,** the battery makers of Dagenham Dock, Essex, has been moved to 137 Victoria Street, London, S.W.1. Telephone: Tate Gallery 9212.

SPHEROIDAL GRAPHITE CAST IRON

The Mond Nickel Company's British Patent No. 630,070 covering the production of spheroidal graphite cast iron by the magnesium process, has now been granted. This grant is the culmination of long proceedings before the Patent Office and the Patents Appeal Tribunal.

The process provides a range of cast irons with double the strength of all previous known types and eliminates the brittleness normally associated with iron castings. These irons are proving of the greatest possible importance to designers in all branches of engineering.

The application for this patent was made in March, 1947, and in May, 1948 the first public disclosure of the process was made simultaneously in Great Britain and the U.S.A.

In October, 1949, the Application was accepted by the British Patent Office, and published. Opposition to grant of the patent was lodged by The Meehanite Metal Corporation on the grounds that the invention had been disclosed in certain prior publications, and that the nature of the invention and the manner in which it is to be performed was not sufficiently and fairly described in the specification.

In June, 1952, after protracted proceedings, the Patent Office gave its decision agreeing to seal the patent. Appeal against the decision was made to the Patents Appeal Tribunal and the hearing before this Tribunal took place on November 10-12th, 1952, when Mr. Justice Lloyd-Jacob directed that the patent should be granted.

This final decision clarifying the Patent position will be particularly welcome to the numerous licensees of The Mond Nickel Company who are actively engaged in the manufacture of spheroidal graphite cast iron by the magnesium process. Similarly for engineers it will remove all doubts about the sources of supply of this important and valuable material.

MACHINE TOOL INDUSTRY IN AUSTRALIA

Prior to the last war production of machine tools and accessories was small, most requirements being obtained from overseas. Aided by the production of certain tools under licence from overseas countries (valid only for the duration of the war) considerable expansion took place in the local industries in the years 1940/45. In view of the wide range of the industry it will be appreciated that it is not possible to assess the Australian demand in physical numbers, but, expansion of industry generally has been responsible for the large increase in the value of items imported in recent years. Local production, however, is still limited to a comparatively narrow range due largely to the small demand for a large variety of items, and the shortage of skilled tool makers.

A number of precision-engineering shops are capable of making machine tools if orders or capacity are available. After the war, surplus government-owned machine tools were rapidly disposed of to industry, but, the continuing demand from new and extended industries resulted in importations to the extent of £3,000,000 in 1947/48, the chief sources of supply being the United Kingdom and the United States of America. There was a slight decline in 1948/49, when total imports fell to £2,200,000, the imports from dollar and hard-currency areas rose by £66,000 to £570,000. This indicates that the decline in 1948/49 was due to import restrictions rather than a lessening of demand. Milling machines (other than gear milling) to the value of £416,640 and £277,000 were imported during 1948/49 and 1949/50 respectively, while grinding machines (other than gear grinders) to the value of £258,870 and £354,880 were imported during the same periods.

It is estimated that the United Kingdom contributes an estimated 90 per cent of all imports of machine tools and accessories and there exists a considerable consumer preference for the British products. In 1947/48 imports from the U.S.A. totalled Australian £500,000 in a total of A.£3,000,000, but, the Dollar shortage and consequent import restrictions has lead almost to a cessation of imports from that country.

There are at present about 18 companies in Australia manufacturing machine tools. A considerable number of engineering firms produced machine tools during the last war, but they have now reverted to other products. Seven firms are important makers of machine tools, six are of lesser importance, but make considerable quantities; five firms make only limited quantities and only one or two types.

CHANGES IN DEFENCE PRODUCTION PROGRAMME

The Minister of Supply, Mr. Duncan Sandys, met representatives of the aircraft industries to discuss with them the detailed effects of the changes in the Defence Production Programme announced by the Prime Minister.

Mr. Sandys explained that although the curve of aircraft production would rise less steeply than had been previously planned, the output of military aircraft would continue to expand.

The labour force engaged on defence work in the aircraft industry was expected to rise by some ten thousand during the next twelve months. In addition there would be a further increase in employment on the civil side as a result of the growing demand throughout the world for British airliners, such as the Comet, the Viscount and the Britannia. The changes in the defence programme might create temporary redundancies in two or three firms amounting altogether to about 2,500 out of a total of over 200,000 employed in the industry.

The changes in the programme had been dictated by the necessity to prevent expenditure climbing beyond the limits of the country's financial capacity.

Mr. Sandys emphasised that decisions to reduce orders for this or that aircraft reflected in no way whatsoever upon its technical or operational qualities. This was particularly true in the case of the Canberra, which was the first of the super-priority types to be brought into service. It was not only being produced as a light bomber for the Royal Air Force, but was also being manufactured in the United States under licence to fulfil the intruder role. The Canberra would, of course, continue to be accorded super priority, as would also the other outstanding new types—the Hunter, the Swift, the Javelin, the Valiant and the Gannet. These advanced types would now account for a considerably larger proportion of the total programme. The fact that the numbers of the other aircraft were being reduced made it more than ever urgent to speed production of the six super-priority types and to ensure punctual delivery to the services.

PEAT BURNING GAS TURBINE

An open cycle internal combustion gas turbine to burn peat has successfully completed its initial test runs at the works of the makers, Ruston & Hornsby Limited of Lincoln. The turbine, of 750 kW

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capacity, has been built under contract to the Ministry of Fuel and Power as part of the research programme into the utilisation of peat resources (which is proceeding in collaboration with the Scottish Home Department, with the general advice of the Scottish Peat Committee).

During the tests, powdered peat was used. A system of feeding the peat and controlling its flow into the combustion chamber has been developed which enables the plant to be run as steadily with this fuel as with oil. Using the experience gained in these initial tests, the plant is now being prepared for prolonged running.

An advantage of this machine is that the hot exhaust gases are available for drying the peat; the quantity of heat is insufficient to dry the peat from the raw state, when it contains about 90 per cent of water, but the plan is to run the turbine in association with a special press designed to remove about two-thirds of the water from the raw peat. This system permits peat to be won independently of weather or season, which is in contrast to the conventional methods employing air drying. It is intended that the programme should culminate in transferring the turbine to a Scottish peat bog where it will be combined with a press and a dryer, which are on order.

G.W.B. INDUCTION MELTING FURNACES

G.W.B. Electric Furnaces Ltd., of Dudley, Worcs., have entered into an agreement with S.P.A. Forni Elettrici A. Tagliaferri, of Milan, to market normal frequency core type Induction Melting Furnaces. The range includes standard furnaces for melting aluminium and other light alloys, copper alloys and also for cast iron. In addition, furnaces are available for zinc distillation in a closed furnace chamber.

The melting is carried out in a channel surrounding a primary winding, a ring of molten metal forming the secondary winding of a 50 cycle transformer.

The melting furnaces for cast iron have been specially developed to work in conjunction with normal cupolas in the duplex process for producing high grade refined irons. Such furnaces can also be used for producing nickel-manganese and nodula cast irons whilst cast iron chips and scraps can be recovered in these induction furnaces with a far smaller metal loss.

For feeding die-casting machines, hand filled moulds etc., melting furnaces, for aluminium and brass, are of the twin chamber bale-out type.

All furnaces are arranged for either hand, mechanical or hydraulic tilt and, in the case of the larger types, a special feature lies in the ability to remove the bath and inductor slots for relining without disturbing the transformer itself or the electrical connections. This means that a spare bath can be held in readiness, relined for immediate use.

NEW BRITISH RESEARCH AIRCRAFT HAS ADJUSTABLE WING

The latest British research aircraft, the Short SB-5, which has now started test flights, has a thin wing with fifty degrees of sweep back, which can be adjusted to different degrees of sweep for investigating performances in varying low-speed conditions.

The SB-5 is the first aircraft produced by the team of designers led by David Keith-Lucas at Shorts. David Keith-Lucas spotlighted new trends in wing design recently in his lecture before the British Association in September.

One new structure discussed was the so-called aeroisoclinic wing, a structural technique for overcoming some of the difficulties brought about by the peculiar form of bending of a sweptback wing in flight.

Another was the crescent-wing in which the angle of the sweepback is reduced across the span.

POWER BOOSTERS FOR AIR FORCE JETS

The latest Royal Air Force jet fighters are having a reheat device fitted to the engine which injects neat fuel into the tailpipe gases to give an instantaneous surge of extra power—30 per cent or more higher than the normal thrust figure.

Pilots use the extra power from the reheat device primarily for very quick get-away and climb. Reheat may also be switched on in actual combat, when its extra power can make all the difference between shooting down the enemy or being shot down. Today's combat takes place at 40 or 50,000 feet where the thrust of a jet engine may fall off from 10,000 at sea level to some 1,650 lb; reheat gives the necessary extra boost for stratospheric manoeuvring.

THE PISTON ENGINE NOT FORGOTTEN

A team of engineers working at Coventry are now building the prototype of an 870 hp engine for small aircraft and helicopters.

The engine is the Alvis *Leonides Major*, developed from the *Leonides* series now in service, and giving half as much power again, though smaller in diameter. Alvis hope to run the new engine on test during 1953.

Some details of the engine are now available. It is a fourteen-cylinder air cooled two-row radial, with push-rods operating overhead poppet valves. Its overall diameter—39 in.—has been described as "incredibly small." A special low pressure fuel injection system enables the pilot to control the engine by a single lever.

Constant speed fully feathering or braking propellers can be fitted. The engine is designed to fly on 100 octane fuel, but, with minor modifications, lower grades could be used. Special baffles give the necessary cooling for tropical operation, long taxying and slow climbs.

British aircraft designers are interested in the engine in two ways; first because it can be put in existing aircraft now fitted with lower-powered piston engines—thus giving them a better performance. Second, designers foresee completely new designs of aircraft, powered by two or four Leonides Majors, which will fill roles at present quite impossible with the gas turbine. An example is a projected Scottish Aviation Twin Pioneer. The engine will also power all the Westland S-55 10-seat helicopters now being built, in place of the existing American engine.

THERMAL MOTOR PROTECTION RELAY

Protection against prolonged overloads of induction motors giving continuous service is not a simple matter if purely electrical methods are employed to operate the protective device. A sustained starting load due to high inertia would normally bring the breaker system into action and the motor would thus never reach the designed running speed.

By using the thermal capacity of the motor, however, the problem can be overcome, and this is the system employed in the new motor protection relays developed by Chamberlain and Hookham Ltd., New Bartholomew Street, Birmingham 5.

Three models of these relays are now available. The H type is designed to protect three-phase star- or delta-connected induction motors against overload or single-phasing conditions where the starting current does not exceed 7 times normal full load.

The type HST provides similar protection for larger motors having starting currents in excess of 7 times full load and where starting conditions may be prolonged by high inertia loads.

Instantaneous protection against short circuit faults is an additional protection obtainable in the type HST/AM. This relay is, in all other respects, similar to the HST.

The principle of operation of the type H relay is that three bimetal spirals, fixed at their centres, receive heat from three metal grids carrying currents proportional to the three line currents energising the motor. The deflection of each bimetal spiral has a direct relation to the current in its associated heater—and, of course, the ambient temperature—but the relative movement of the free ends of the spirals is only a function of the difference between the currents flowing in the associated motor lines.

The free end of the centre spiral is terminated in two forked contacts the members of which "enclose" single contacts secured to the other two spirals. Each fork has its prongs spaced so that a 12 per cent difference in the currents of adjacent elements will cause engagement of the appropriate single contact. Current will then flow to operate a breaker system and the indicator described later. Thus any phase unbalance of 12 per cent at 100 per cent load will operate the protection device.

A fourth bimetal spiral has no associated heater and is sensitive only to changes of temperature. The outer end of this bimetal spiral is attached to the free end of one of the heated spirals described above and the inner end, which is freely pivoted, is attached to an arm terminating in a contact. The movement of this contact is

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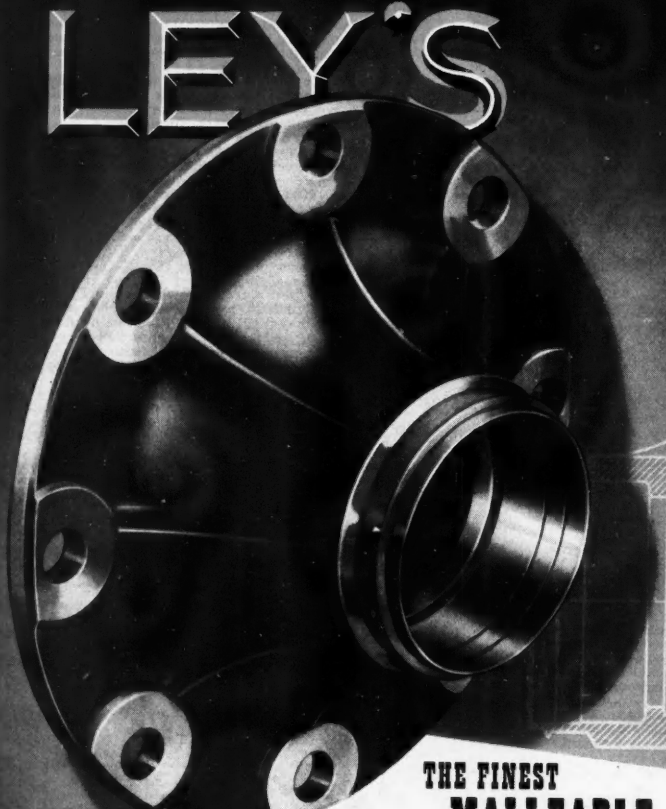

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dependent only on the heat supplied to the adjacent heated bimetal spiral since the deflection of the unheated spiral due to ambient temperature change is in the opposite direction to that of the heated bimetal. A scale is fixed in proximity to the contact arm, calibrated in percentage of full load, and an adjustable contact is arranged on the scale so that it may be engaged by the contact arm at any predetermined line current between 50 per cent and 150 per cent of normal full load. This device provides overload protection.

The spirals, heat aged during manufacture and gold plated to ensure no change in surface texture, are individually calibrated and groups of four spirals having the same constants are selected for each unit.

Tripping indicators, of conventional attracted armature pattern operated electrically when the main contacts close, can be fitted to any model.

The indicator can be arranged to be connected in series or parallel with the trip coil. Each contactor is fitted with two change-over contacts which can be connected as two normally open, two normally closed or one open and one closed. The indicator is of a new design incorporating a flap which is rotated through 180° about one edge. The flap normally covers a plate of its own size but on rotation exposes the plate together with its own reverse side.

The type HST relay employs precisely the same principles but the heaters are supplied from three saturable transformers. These transformers are designed to saturate in such a manner as to modify the operating time current curve and thus allow a larger starting time for motors with high inertia loads. Also, heavy starting currents can be accepted by the relay since the output current of the transformer is considerably lower in proportion to the input current than in the type H.

Type HST/AM incorporates all the features of the HST and, in addition, is fitted with three instantaneous relays, type AM, each connected in series with a saturable transformer. The instantaneous element is essentially based on the tripping indicator described previously but includes a setting adjustment for selecting the current at which it should be operated. The connections can be arranged to include three overcurrent elements or two overcurrent elements and one earth fault element.

THE ARCTIC COMES TO THE MIDLANDS

The conditions on an Arctic airfield are now being recreated in a test chamber at a Birmingham factory. Experiments being made there are giving scientists valuable data on the use of Polar regions as commercial and military air bases.

The tests being made are on rubber—its behaviour in aircraft and vehicles in low temperatures. Oil seals, washers, clothing, oxygen masks, and in particular tyres, are all being checked.

As the temperature falls, natural and synthetic rubber begins to stiffen. Below about minus 56° C, natural rubber loses most of its rubber-like qualities—and synhtetic rubber often even sooner. It is virtually useless as a shock-absorber below this temperature, and if an aircraft were to land, all the shock of the touch-down would be transmitted direct to the airframe—with disastrous results.

Up to about minus 40° C natural rubber is still slightly flexible but once its shape is changed it only returns to its moulded shape very slowly. This means that if an aircraft were to land on an Arctic base at this temperature, the big bulge in the tyre at the point of impact might continue to bulge as the wheel revolved—which would cause a sudden jamming as the bulge tried to turn through the fork of the undercarriage legs.

Again, if an aircraft were parked in the open, the tyres might be flattened where they were in contact with the ground. The flatness would freeze hard, and the pilot might find it very difficult to get the wheels rolling and the aircraft moving again.

The tests being done by Dunlops at Birmingham involve trying out new materials in a cold test chamber. Complete tyres are also "flown, landed and taken-off" in the chamber and checked at various temperatures. Scientists watch the results through a glass panel windscreen made of aviation air-spaced, de-misting Triplex.

Scientists have been posed with the problem of not only checking tyres at these temperatures, but of working down as low as minus 90° C, and finding a rubber, too, which retains its qualities in normal Birmingham temperatures as well as cold.

TWENTY-FIVE YEARS OF INDUSTRIAL PHOTO-ELECTRIC EQUIPMENT

Radiovisor Parent Ltd. have recently celebrated their 25th year as designers and manufacturers of photo-electric equipment. They were the first company to develop industrial photocell applications in this country, and in 1927 patented the first really practical commercial light-sensitive cell.

Naturally there was reluctance on the part of engineers to adopt light-actuated control equipment and they were not at all anxious to use thermionic valves because they were convinced that these were too fragile for engineering purposes. In contrast to this outlook, it is interesting to note how many valves are fitted into present-day aircraft: for instance, approximately 400 valves of various types are used in the modern bomber. Radiovisor Parent Ltd. expended considerable effort and showed much ingenuity in developing sensitive relays that would operate directly from light-sensitive cells. These relays operated on current changes as small as 30 micro-amps, and some idea of the success obtained is gained from the fact that items of this earlier equipment are still in use to-day, having given continuous service for over 20 years. The first light-sensitive street lighting unit employed these relays, and considerable numbers were installed on lamp-posts all over the country.

To-day, thousands of street lamps are fitted with photo-electric lighting controls which switch on the lighting at dusk and off at dawn, and one municipality recently reported that in an installation of six lighting units installed ten years ago, only two valves have been replaced and no light cells. This is exceptional, but long life is now expected from, and given by, such equipment.

The Company also produced the first industrial smoke density indicator, the original unit being installed in 1930. Gradually Power Stations began fitting this valuable aid to combustion efficiency, and units which were installed in the early 1930's are still in use.

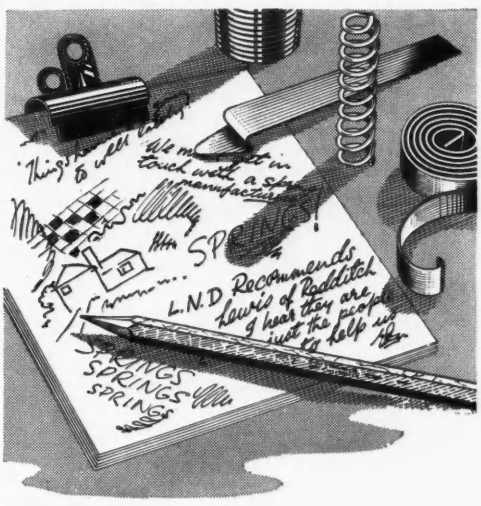
During the intervening years considerable progress has been made in both equipment and technique, and the Company's records and patent library show that most present-day industrial light-actuated equipments originated in their laboratory. As far as is known, they are the only firm who can claim to have devoted their entire efforts to this type of control over so many years.

To-day there is hardly any industry that does not employ photo-electric equipment, and the reliability placed on this form of control gear is shown, for instance, by the countless number of oil-fired boilers which rely on photo-electric Flamestats for protection against flame failure, and also by the recommendations recently issued by H.M. Inspector of Factories covering photo-electric press guards. To mention but a few, other modern industrial uses include such widely diverse applications as automatic temperature control during certain heating and welding operations, high-speed counting, the control of hopper contents, checking the turbidity of liquids, the detection of faults in the surface of carbon paper, the registration of printed material, etc.

THE TECHNOLOGY OF AUTOMATIC WELDING IN THE SOVIET UNION

(*Continued from page* 411)

Full mechanisation suitable for short joints and joints with a space curvature which abound in the construction of rolling stock and other products of mechanical and transport engineering had been given up as an unrealistic aim. A decisive step in this evolution was the separation of the mechanism for electrode feeding from the welding point, but not until the diameter of the electrode was reduced to 2 mm and the design of the hose which surrounds the electrode wire advancing through



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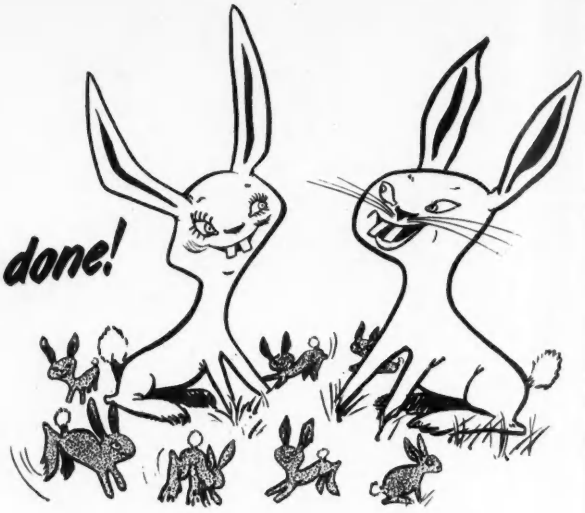

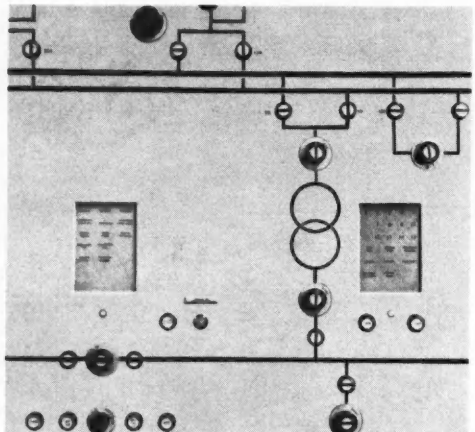

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it was adapted to make it into a current lead, did a thoroughly practical combination emerge.

A complete installation is shown in Fig. 1 (p.411). Electrode wire of 2 mm diameter is unwound from the reel (1) by the feeding mechanism (2) through a hose (3). The hose serves for the supply of current and terminates at the hopper (4). The hopper (4) is part of the electrode holder. The holder also carries starting buttons. The feeding mechanism and wire magazine (2) is light and portable and enables a large floor space to be served from a fixed position of the supply point.

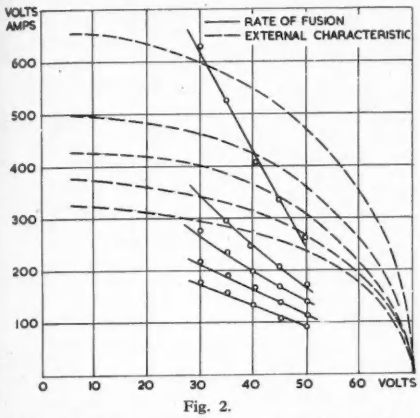

Fig. 2.

Theoretical and practical tests have shown that the property of the thin electrode wire, of particular importance to the utility of the hose apparatus, is the extraordinary stability of the arc within a wide range of currents, provided the open-circuit voltage of the welding transformer and the composition of the flux are suitably chosen. The stability of the arc is illustrated by the sequence which follows an accidental shortening of the arc gap. Such a shortening is accompanied by a reduction of voltage across the gap leading to a rise in current and an even greater rise in the rate of fusion of the wire, which, in turn, restores the original length of the gap. Clearly, the degree by which the rate of fusion rises with decreasing voltage decides the time in which the gap length is restored to its original value. Figure 2 shows in two families of curves the external characteristics and the rate of fusion of the submerged arc, each curve corresponding to a value of the open-circuit voltage. Analytical evaluation shows that the restoration time, suitably defined, varies from one tenth to

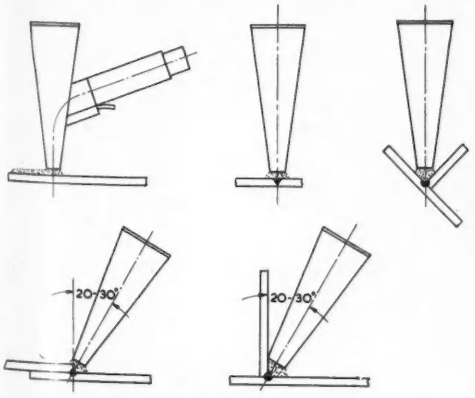

Fig. 3

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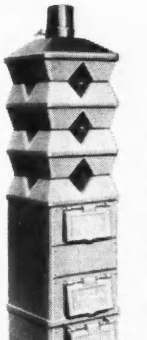

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one half of a second between short-circuit currents of 650 to 300 A. This range corresponds to a range of working currents down to 200 A. Beyond this, the stability of the arc is inadequate. To reduce the current below this value, the a.c. supply must be replaced by a d.c. supply connected with reversed polarity. In this case, a constant rate of feed of electrode wire can be maintained down to 140 A with adequate stability. This allows the welding of steel as thin as 2 mm.

Figure 3 shows the relation between the joint and the electrode holder for various types of joints. The electrode holder is guided manually and its weight is wholly supported by the operator. Experience shows that without any special skill an operator can maintain a sufficient uniformity of gap to produce, with a constant rate of feed of electrode wire, a very competent seam.

The flux used for this type of semi-automatic welding, containing a moderate amount of CaO_2, is distributed under the designation AH-348. The flux is used in a finely granulated state which reduces its consumption because a good isolation of the arc with a small layer of flux permits welding with a minimum distance between the component and lower edge of the hopper.

Certain manual tricks can be employed by more skilful operators, such as swinging the welding arc to and fro across the joint to obtain a wider seam and a more shallow one. This may be advisable with large clearances between joint edges, with inclined joints, with rising joints, for welding on a layer of metal, and in other cases.

(To be continued)

BOOKS.

Hydraulic Research in the United States. By Helen K. Middleton and Sonya W. Matchett. National Bureau of Standards Miscellaneous Publication 205, 200 pages. Price: $1.00, plus 33c. postage for countries outside the U.S.A. Government Printing Office, Washington 25, D.C.

The information contained in this publication was compiled from reports on current projects by 100 hydraulic and hydrologic laboratories in the United States and Canada. The co-operating agencies include 6 industrial laboratories, 1 professional society laboratory, 53 college and university laboratories, 2 state laboratories, 33 United States government laboratories, and 5 Canadian laboratories (including 4 university laboratories and 1 government laboratory).

The projects are listed chronologically and can be readily referred to by means of a list of the laboratories or sponsoring institutions and a comprehensive subject index. The volume also includes lists of foreign publications and translations which are available on loan from various laboratories. A list of the many national hydraulic and hydrologic committees and a section containing notes from a number of laboratories are appended.

The National Bureau of Standards does not have in its files reports or detailed information regarding the research projects reported by other organisations. Such information may be obtained directly from the laboratories as listed in this volume. The laboratories listed are willing to supply information to properly qualified inquirers.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.1)

Glossary of Terms (with Symbols) Relating to the Welding and Cutting of Metals. (B.S. 499 : 1952). In view of the magnitude of the subject it was decided to divide the Glossary into a number of sections dealing respectively with:—

(a) Terms common to most types of welding.
(b) Welding with pressure.
(c) Fusion welding (welding without pressure).
(d) Brazing and bronze welding.
(e) Testing.
(f) Weld imperfections.
(g) Scheme of symbols.
(h) Cutting.

The entire publication is fully illustrated with sketches and line drawings: the section on radiographic examination includes reproductions of radiographs and the scheme of symbols is profusely illustrated with examples showing its application. An interesting item is a chart showing the derivation of the various welding and cutting processes The publication is completed by means of a fully crossed-referenced index of all terms dealt with. Price 21/-.

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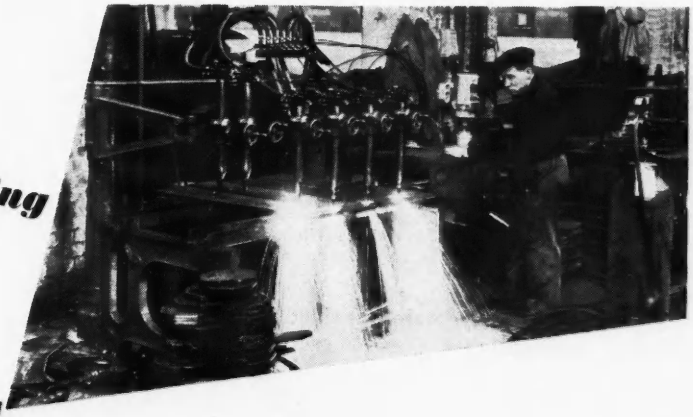

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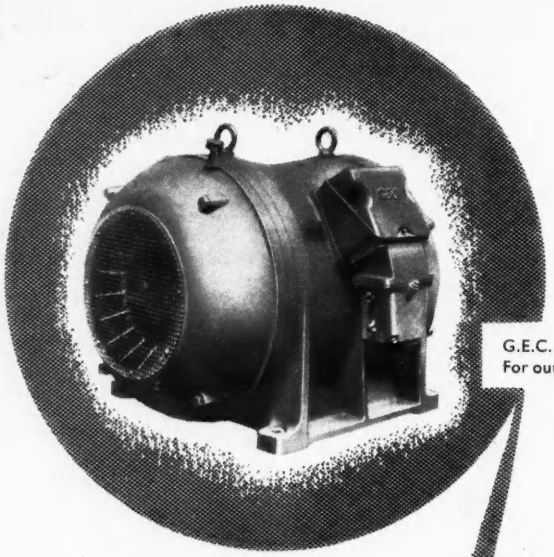

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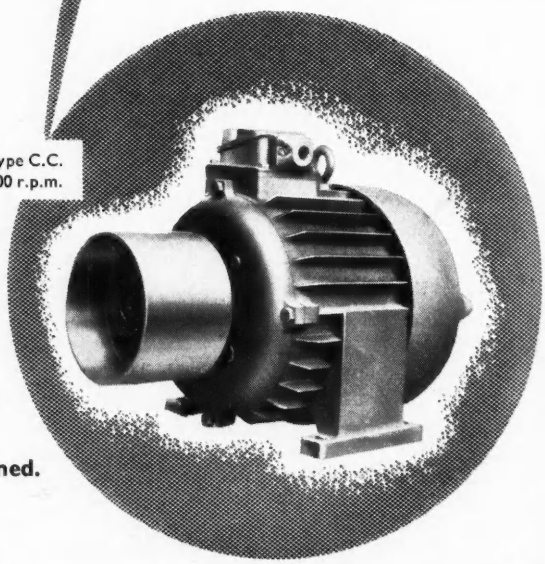

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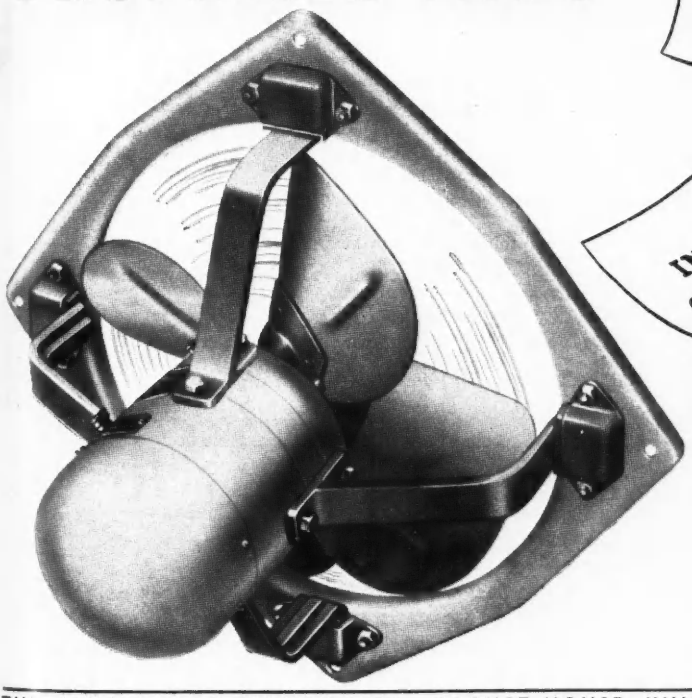

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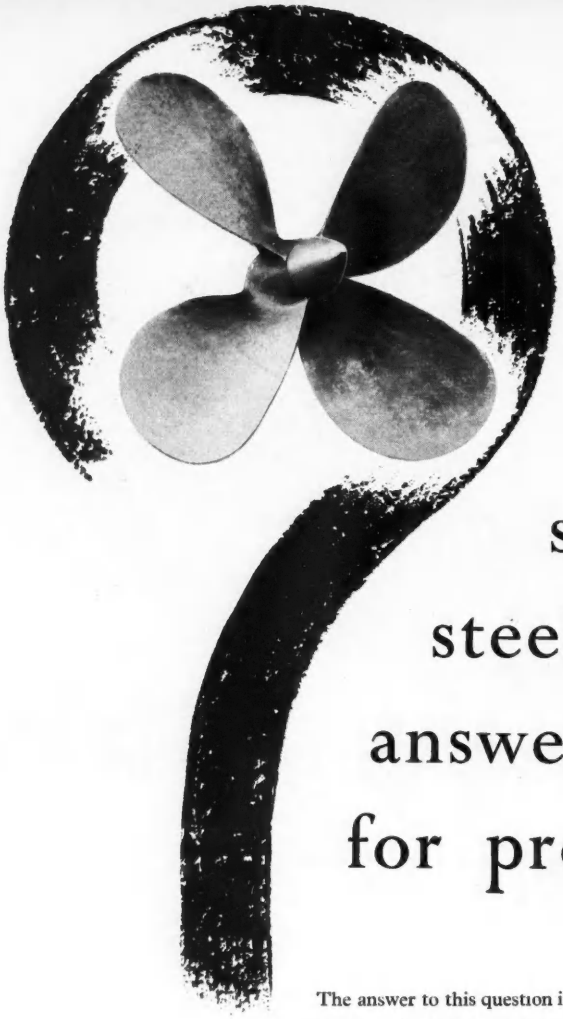

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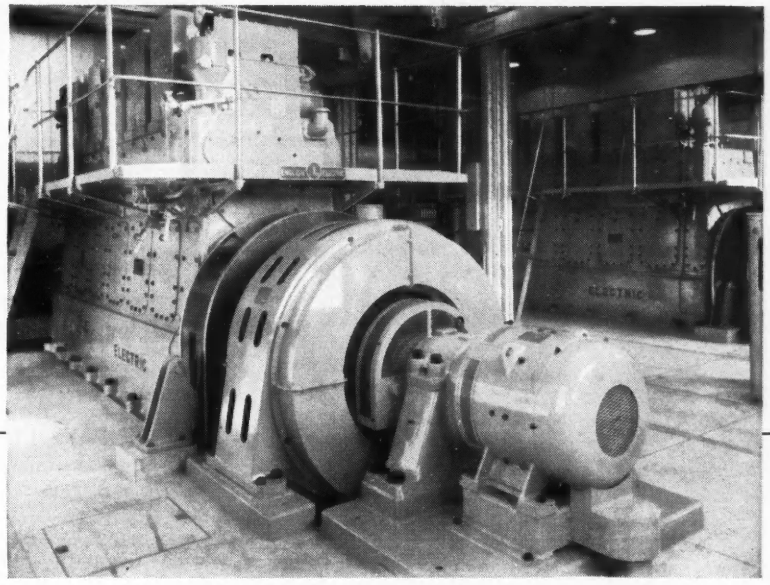

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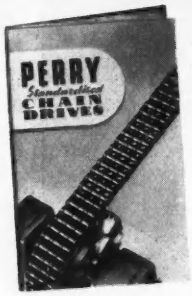

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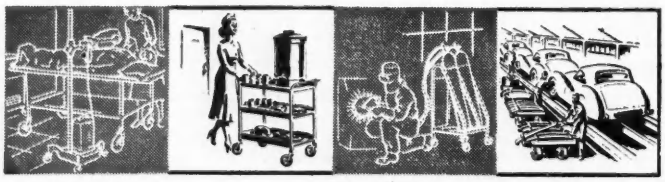

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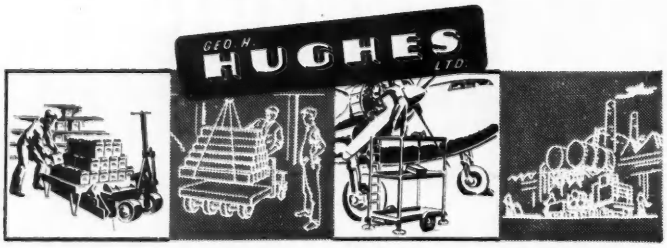

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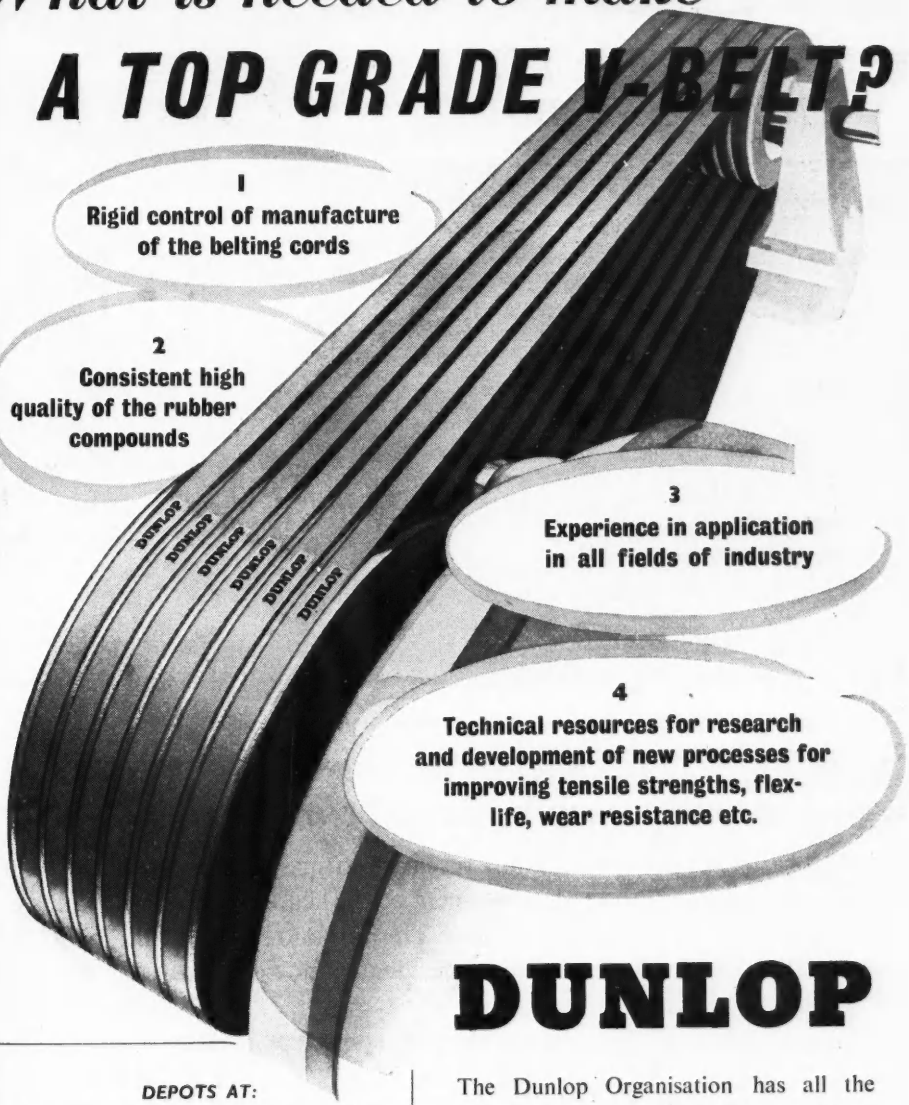

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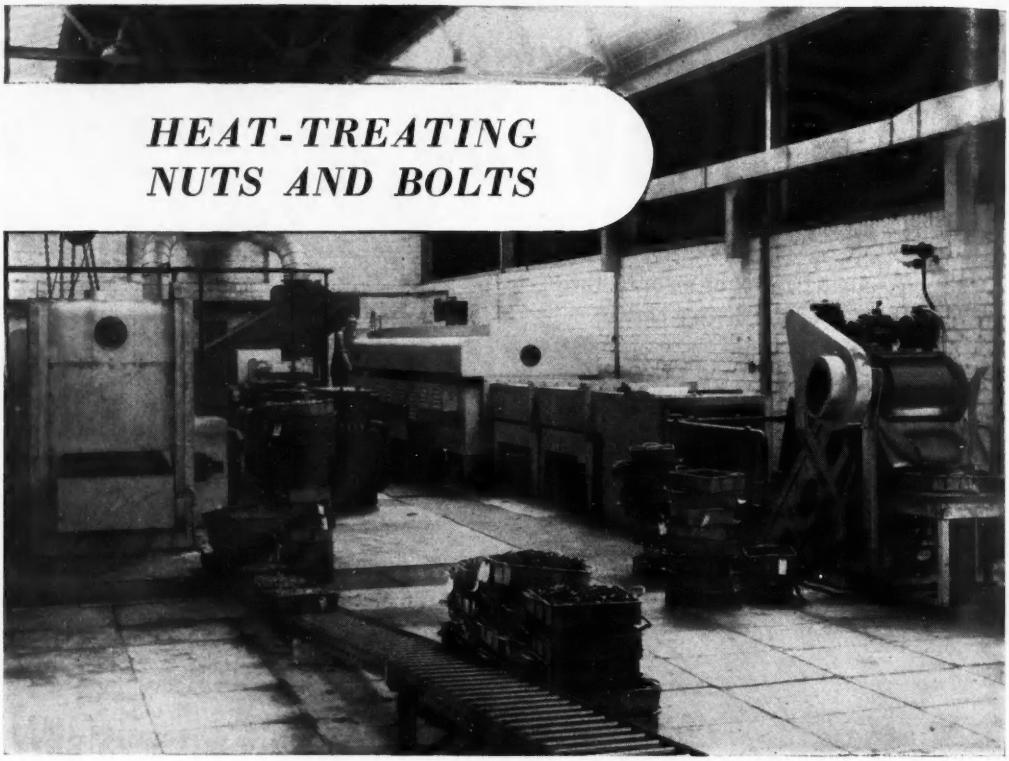

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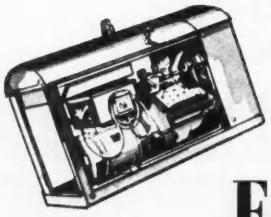
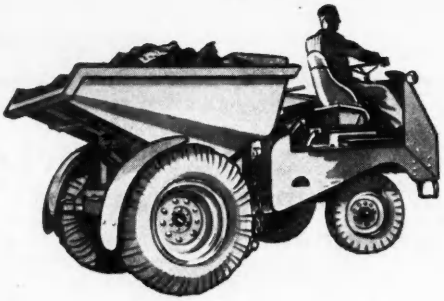
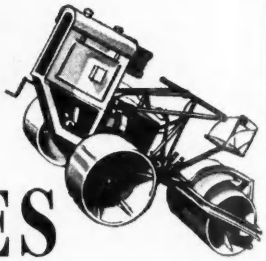


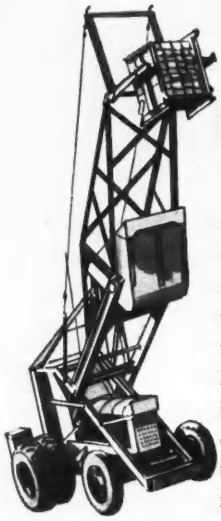




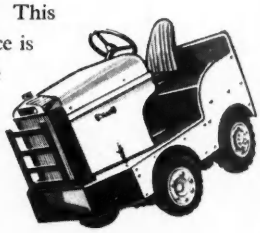
FORD ENGINES

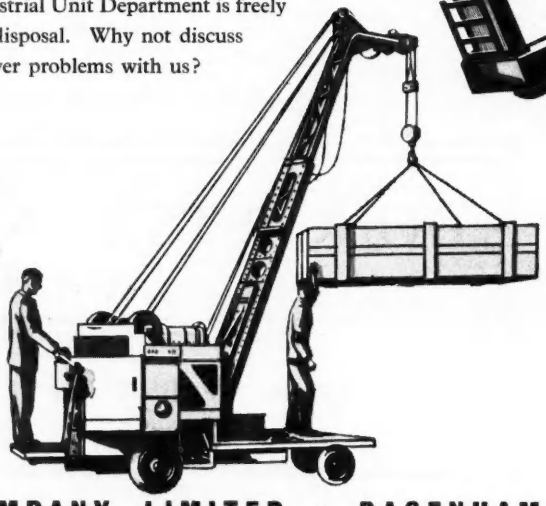
for

INDUSTRIAL EQUIPMENT



Ford Industrial engines are widely used in providing power for Industrial Machinery of every description and have a power range between 10 and 60 B.H.P. when required for continuous working purposes. They are inexpensive to buy and economical to run. They give you long and trouble-free service, and what little maintenance they need is promptly and speedily carried out by Ford Service, which covers every part of the country. This combination of a first-class product and first-class service is the reason why Ford engines hold an unchallengeable reputation in every branch of industry. The advice of our Industrial Unit Department is freely at your disposal. Why not discuss *your* power problems with us?





FORD MOTOR COMPANY LIMITED • DAGENHAM • ESSEX

A crank with a heated bearing...

. . . defended himself vigorously. "I wouldn't refuse to do a good turn for anyone," he protested, "but really, all this work!" The machine shop foreman moved closer and whispered in his gear. "Just between you and me," he murmured, "it's rumoured that you are to be fitted with Tecalemit Automatic Lubrication!" The crank spun round swiftly. "In that case," he said, "I shall grind no more axis!" The machine shop foreman sighed with relief and went to prepare for the arrival of his oil highness—the Tecalemit man.

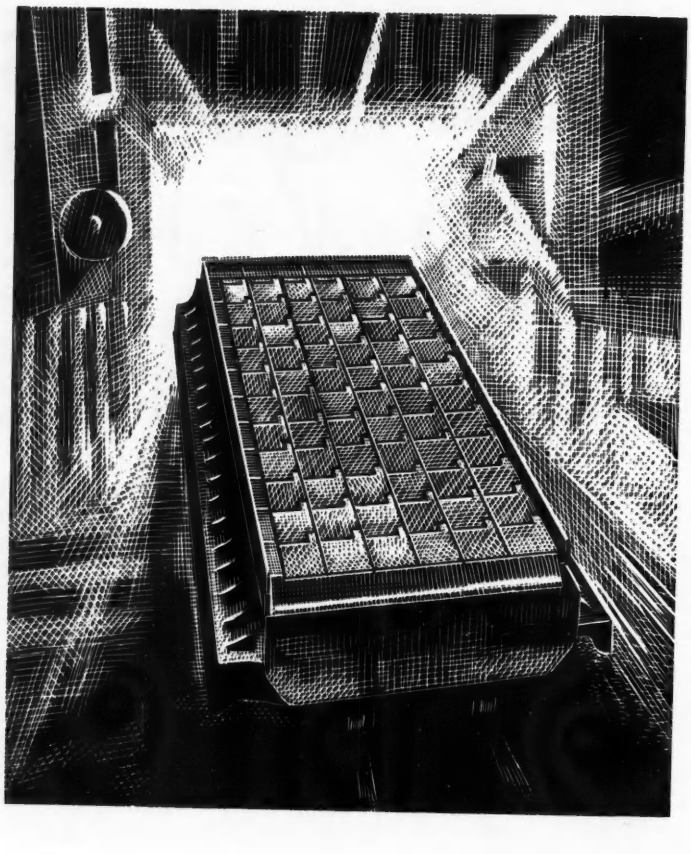
Tecalemit lubrication systems—fully automatic, semi-automatic or manually operated—feed every bearing with the correct amount of oil or grease at the correct intervals of time, regularly... unfailingly... efficiently. A Tecalemit engineer will gladly call to discuss your particular lubricating problems with you.

TECALEMIT

The Authority on Lubrication

PLYMOUTH, ENGLAND

T402



HEAT RESISTING STEELS

The illustration shows a 'Javelle' Furnace Hearth.

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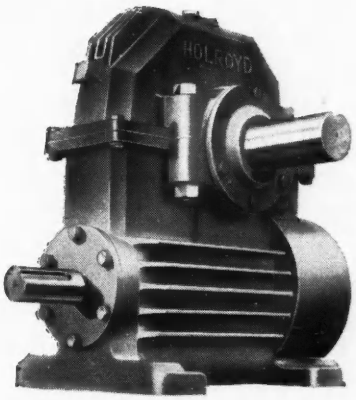
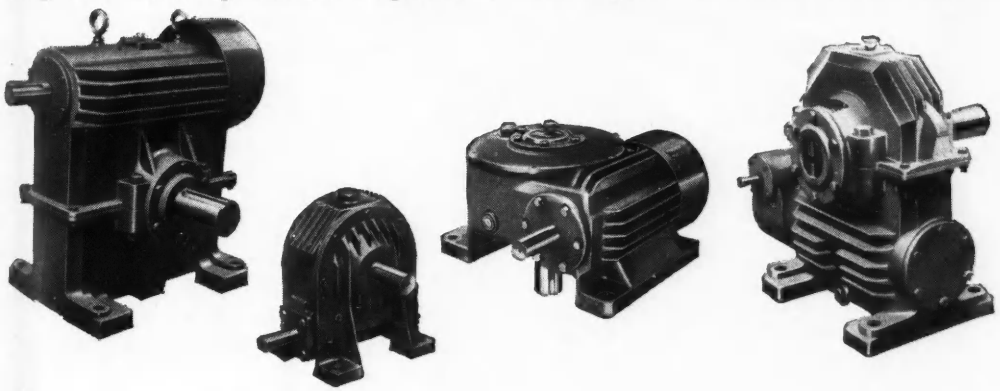
SHEFFIELD

HADFIELDS LTD., EAST HECLA WORKS, SHEFFIELD, ENGLAND



meet the boys . . . . Some of our customers tell us they don't know how many types of Totally Enclosed Worm Reduction Units we make. Well! Here they all are. The big fellow at the top is our Underdriven (Standard) Worm Reduction Unit — comes in any size from 3″ to 24″ centres, and ratios from 5/1 to 70/1. Then, first on the left below, our Overdriven W.R.U. — same range of centres and ratios but with driving shaft at top. Little Tich is our F. Type for fractional horsepower — 3 sizes: $1\frac{1}{2}$″, $1\frac{3}{4}$″, and $2\frac{1}{2}$″ centres each with 3 different relative positions of the input and output shafts. It may be mounted with the feet in any plane. The fat flat chap is our Vertical Type — same range as the Standard, but with a vertical wheel shaft that can be extended above or below the box. And last but far from least, our Double Reduction Unit for ratios up to 3000/1. Tough looking lot, aren't they! Tough, hard-working and reliable as a bevy of iron-jawed bank managers.

Holroyd Gear Reduction Units



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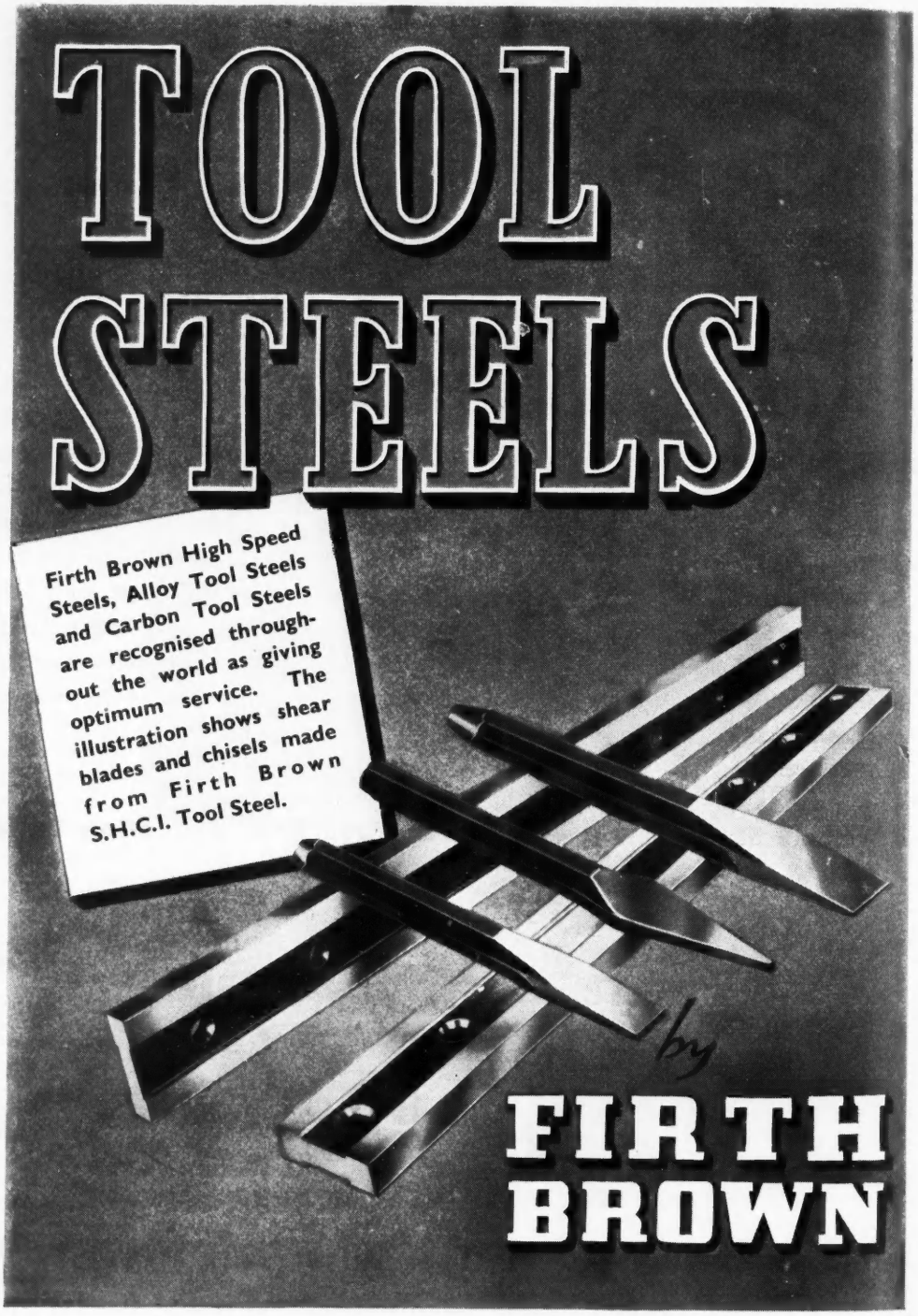
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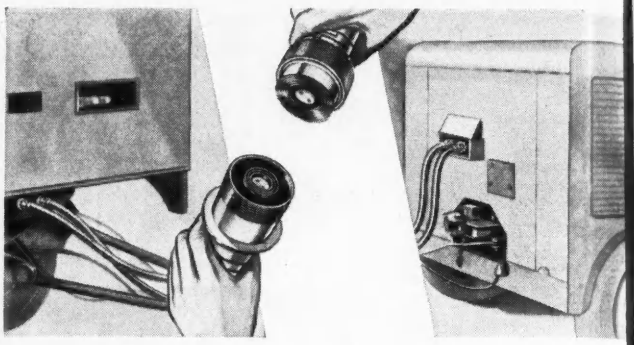
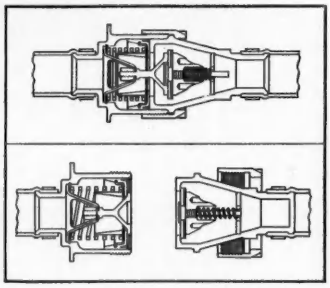


With an Exactor Coupling, a pipe line can swiftly be cut and reconnected—without a drop of the fluid it carries escaping. No air enters the pipeline. Foolproof, completely automatic. Thousands in daily use in all branches of industry. Write for technical leaflet.



There is an automatic valve in each half of a Exactor Coupling. When the coupling is join ed, the valves mate and keep open by mutua pressure. When you uncouple, each valv seals its side of the break. Full range of size from ⅛" to 7" bore, for high and low pressures

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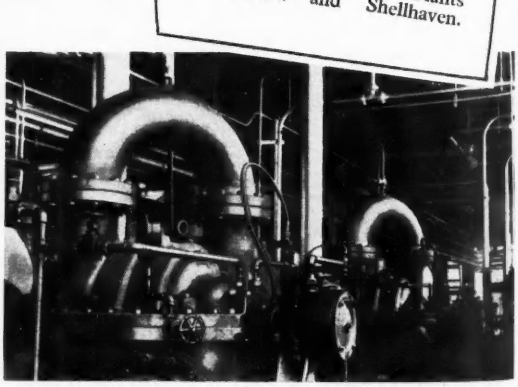

Main charging pumps in a Petroleum Refinery in Venezuela.

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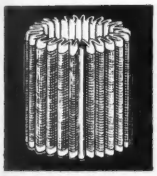
IS *ALL THE OIL* BEING FILTERED *ALL THE TIME?*

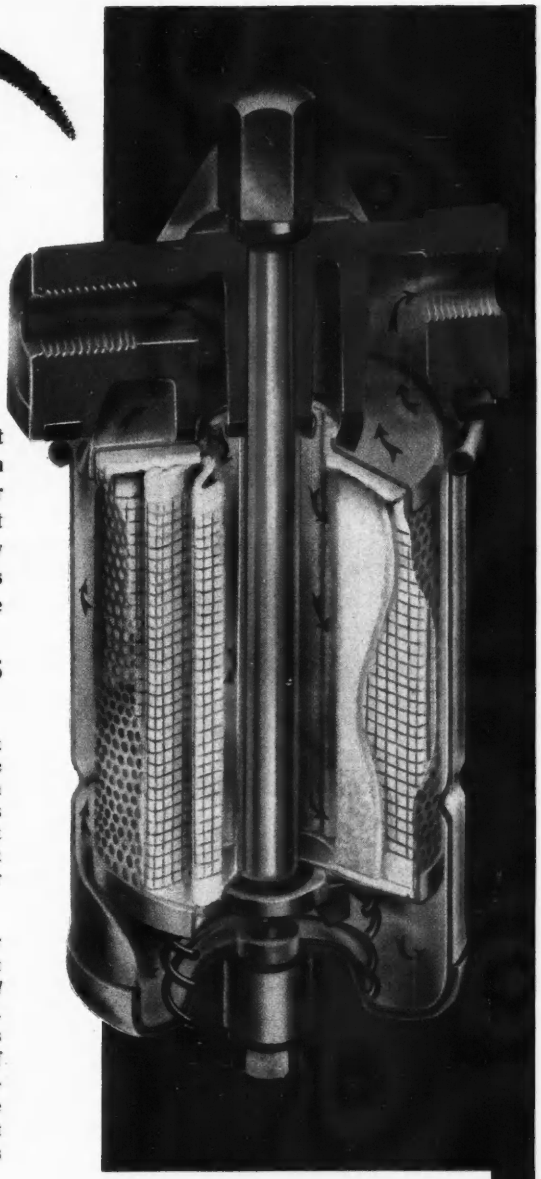
That is the vital question which must be asked when considering filtration claims. Engineers today accept the fact that for real protection, partial flow filtration is not enough. But remember! even a so-called *full* flow filter can allow irreparable damage if the by-pass comes into operation for *long* periods when the oil is cold.



CONSIDER THE FAMOUS VOKES ELEMENT

Here is the VOKES filter element —unchanged in principle because thirty years of constant research have found nothing better. By its principle of "filtration-in-depth" it avoids the possibility of particles being driven straight through the filtering medium and also ensures a slower build up of surface sludge.

This then is the vital point. If a so-called full flow filter cannot cope with the oil when it is cold and sends it direct into the engine, then it is not filtering *all* the oil *all* the time. Consider, too, the question of "cleanability". This is highly important where plant and machinery is operating in remote areas, avoiding the possibility of equipment being put out of service through the non-availability of expendable elements. Also, although the VOKES element may cost a little more in the first place, the fact that it can be cleaned several times gives long-term economy.



The VOKES direct flow device is a safeguard to the engine and not just to the filter itself. It comes into operation only under *abnormal* conditions and *not* for long periods merely because the oil is cold. When it is called upon, however, it is truly foolproof. Illustration (left) shows flow through filter element. Illustration (right) shows by-pass flow.

VOKES

Pioneers of scientific filtration

V61

VOKES LIMITED GUILDFORD SURREY

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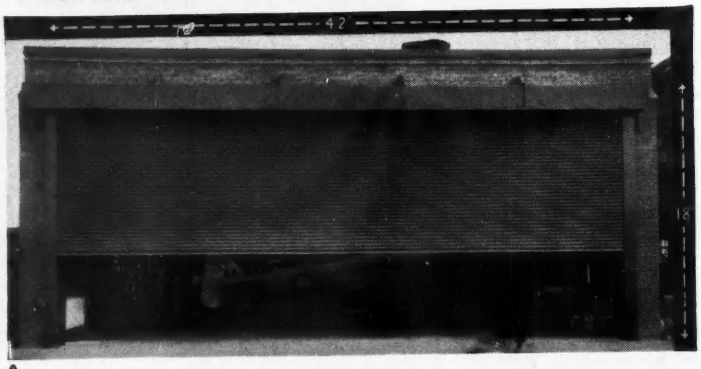

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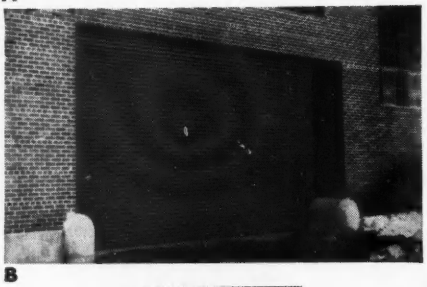

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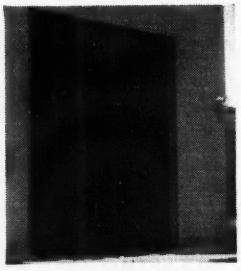

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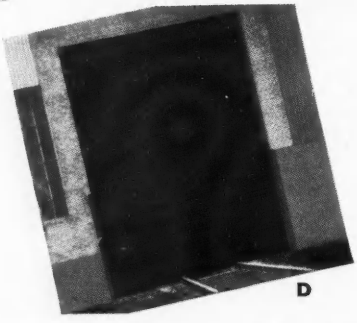

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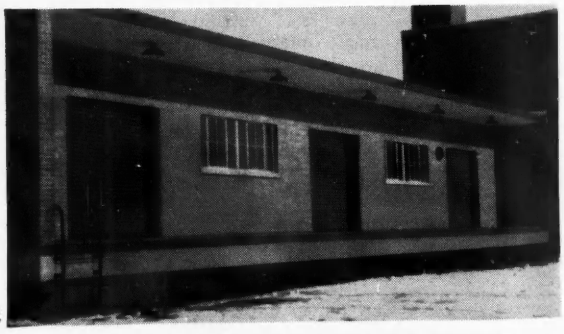

E

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A *Giant shutter installed for the Canadian Car & Foundry Company Ltd., Montreal.*

B *Steel gear-operated shutter installed for Firth Brown Tools, (Canada) Ltd., Montreal.*

C *Steel gear-operated shutter installed for Goodyear Tyre & Rubber Company of Canada Ltd., Montreal.*

D *Steel gear-operated shutter installed for Grinnell Co. of Canada Ltd., Montreal.*

E *3 Steel gear-operated shutters installed for Goodyear Tyre & Rubber Company of Canada Ltd., Montreal.*

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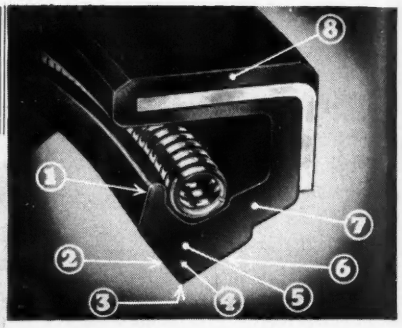

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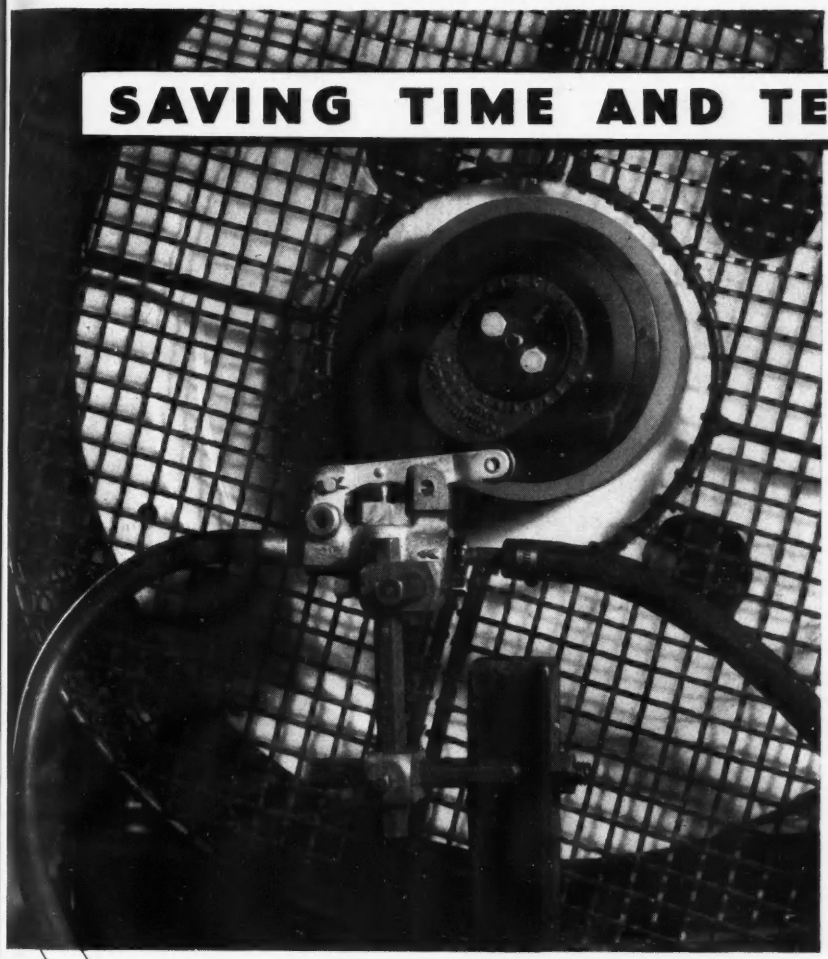

We illustrate the tripping mechanism of a Schrader Air Ejection Set fitted to a rear flywheel press at the Wembley works of Johnson, Matthey & Co. Ltd.

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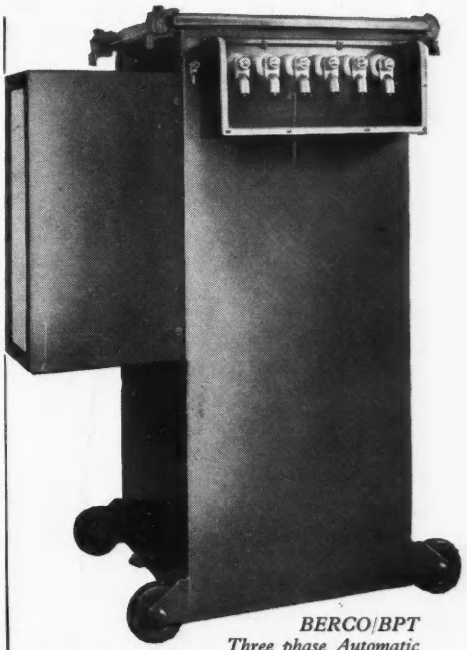

BERCO/BPT
Three phase Automatic Stabilizer, oil immersed type, showing cable entry box and compartment housing control gear.

BERCO
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For constant voltage use a model from the wide range of Automatic Stabilizers made by British Power Transformer Co. Ltd., for single and three phase supplies. For variable voltage select a "Regavolt" from the wide range of models made by The British Electric Resistance Co. Ltd.

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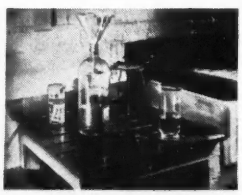

A Tufnol draining board in a photographic dark room after thirteen years' service.

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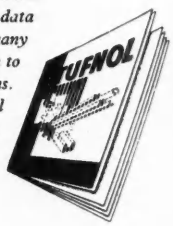

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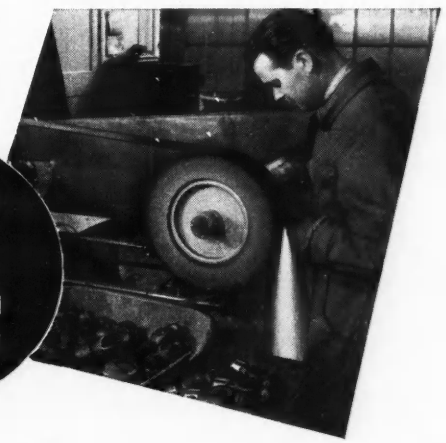
★ *The 3M Company invites you to visit their demonstration rooms in London, Birmingham or Manchester for expert advice on the application of coated abrasives.*



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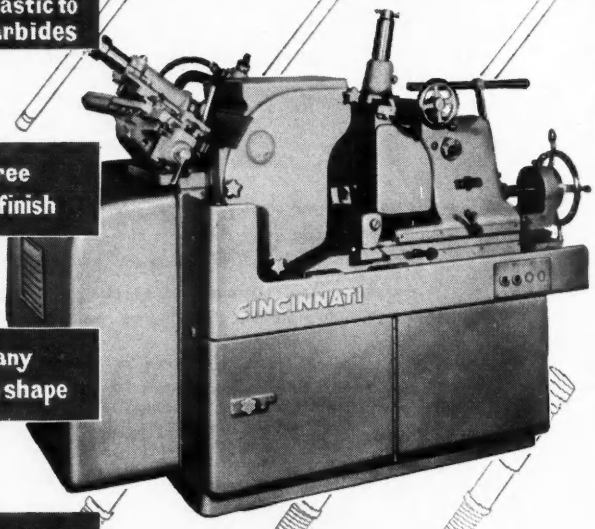

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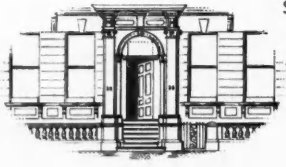

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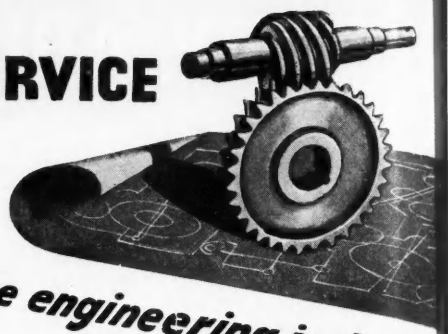

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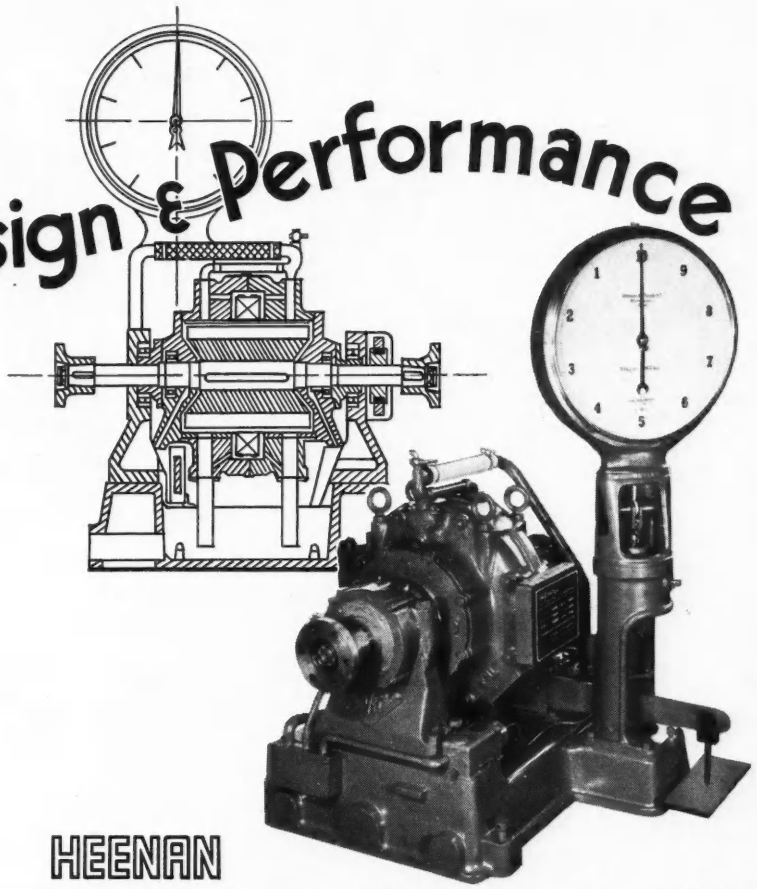

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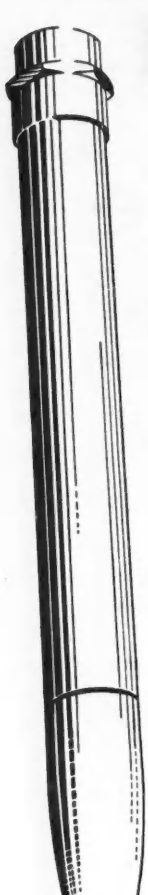

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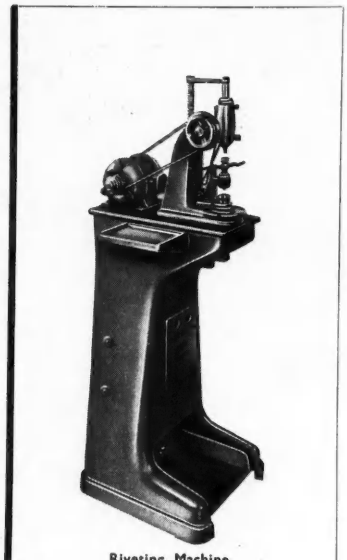

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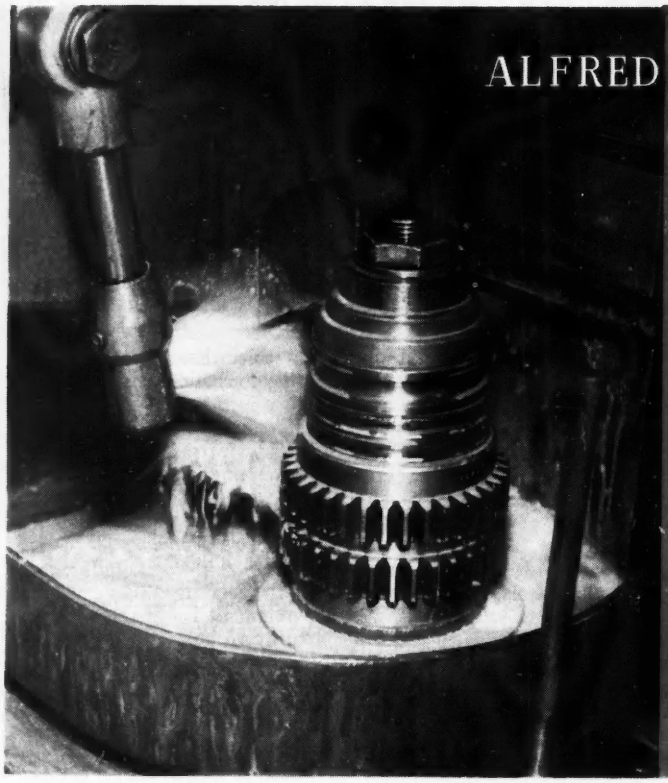

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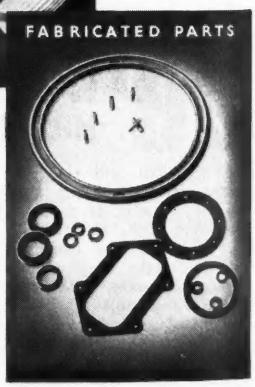

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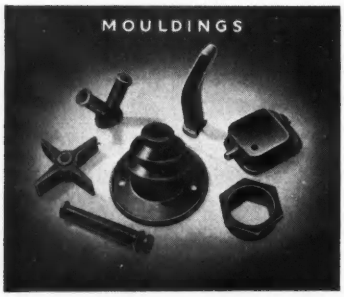

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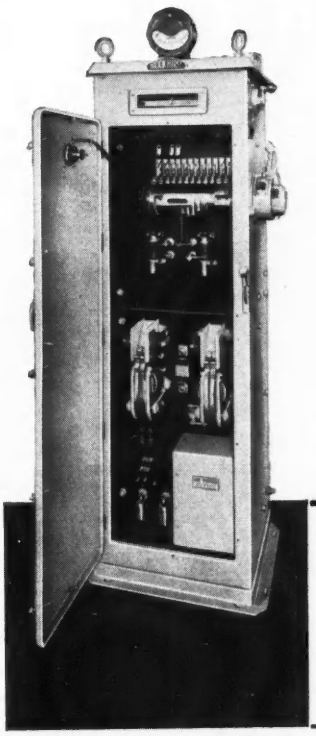

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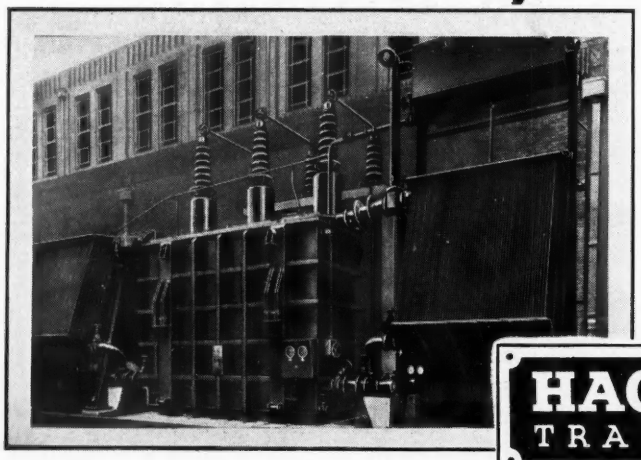

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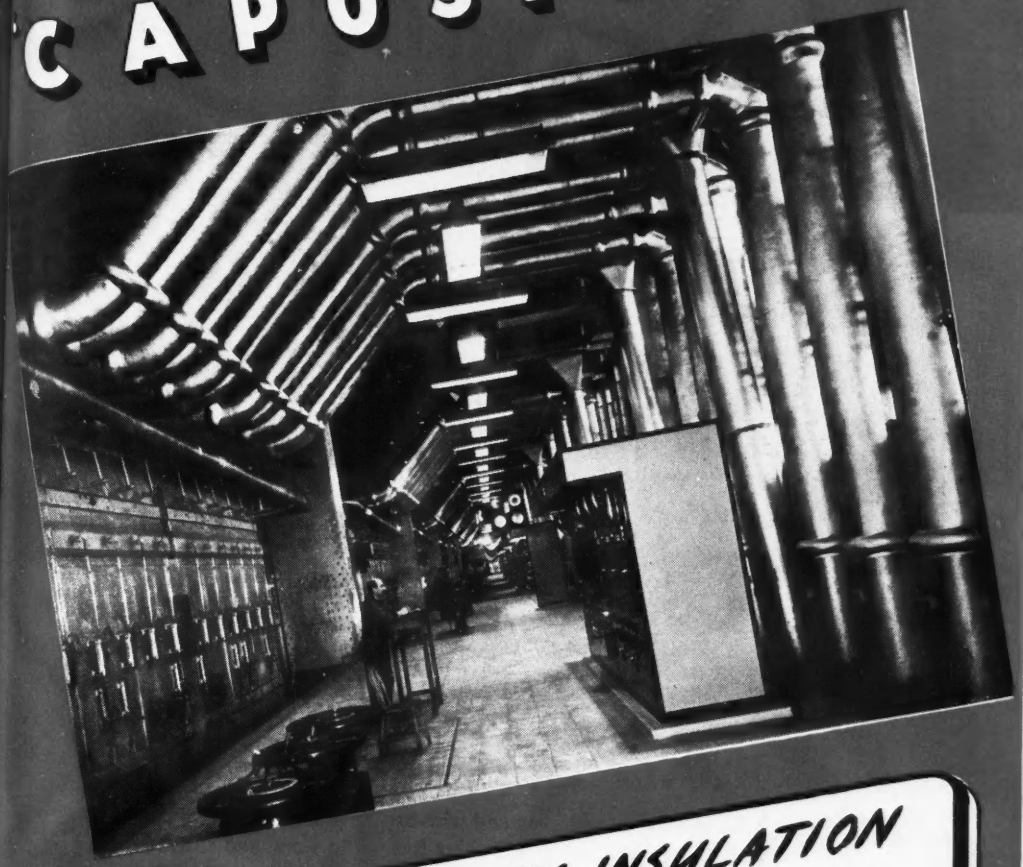

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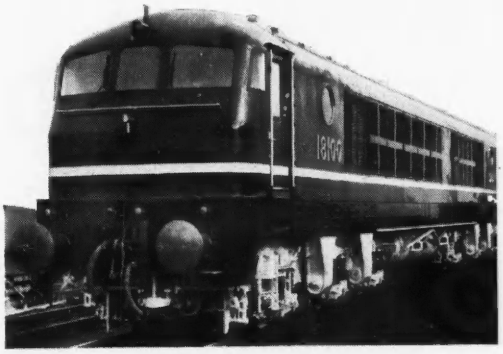
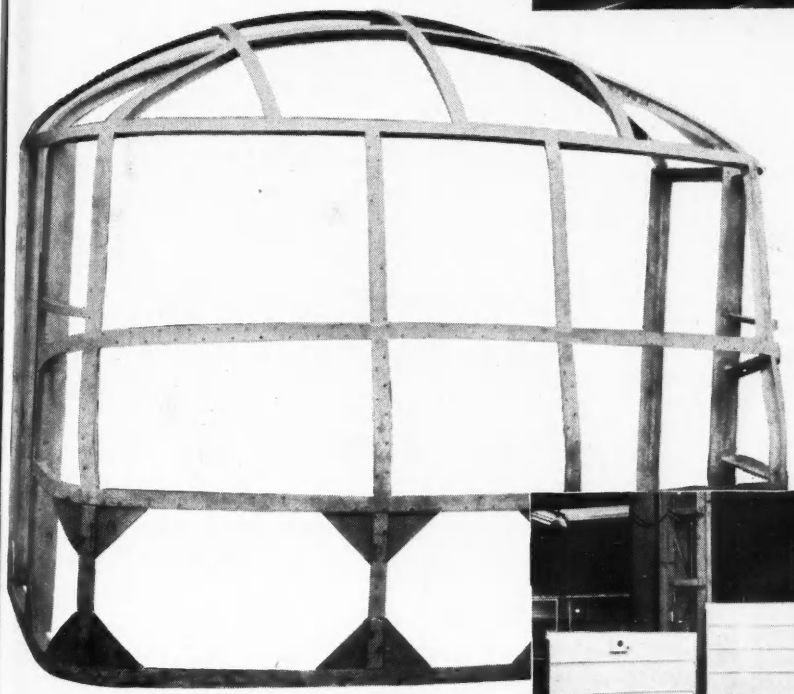
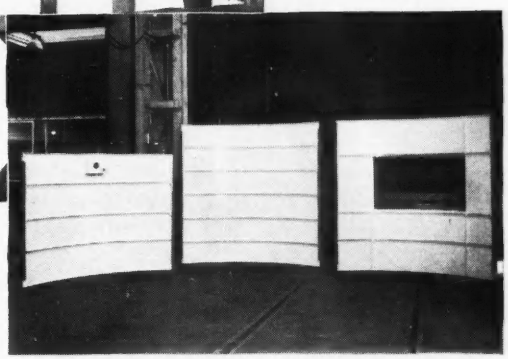




Details of cab construction in 'MG3'



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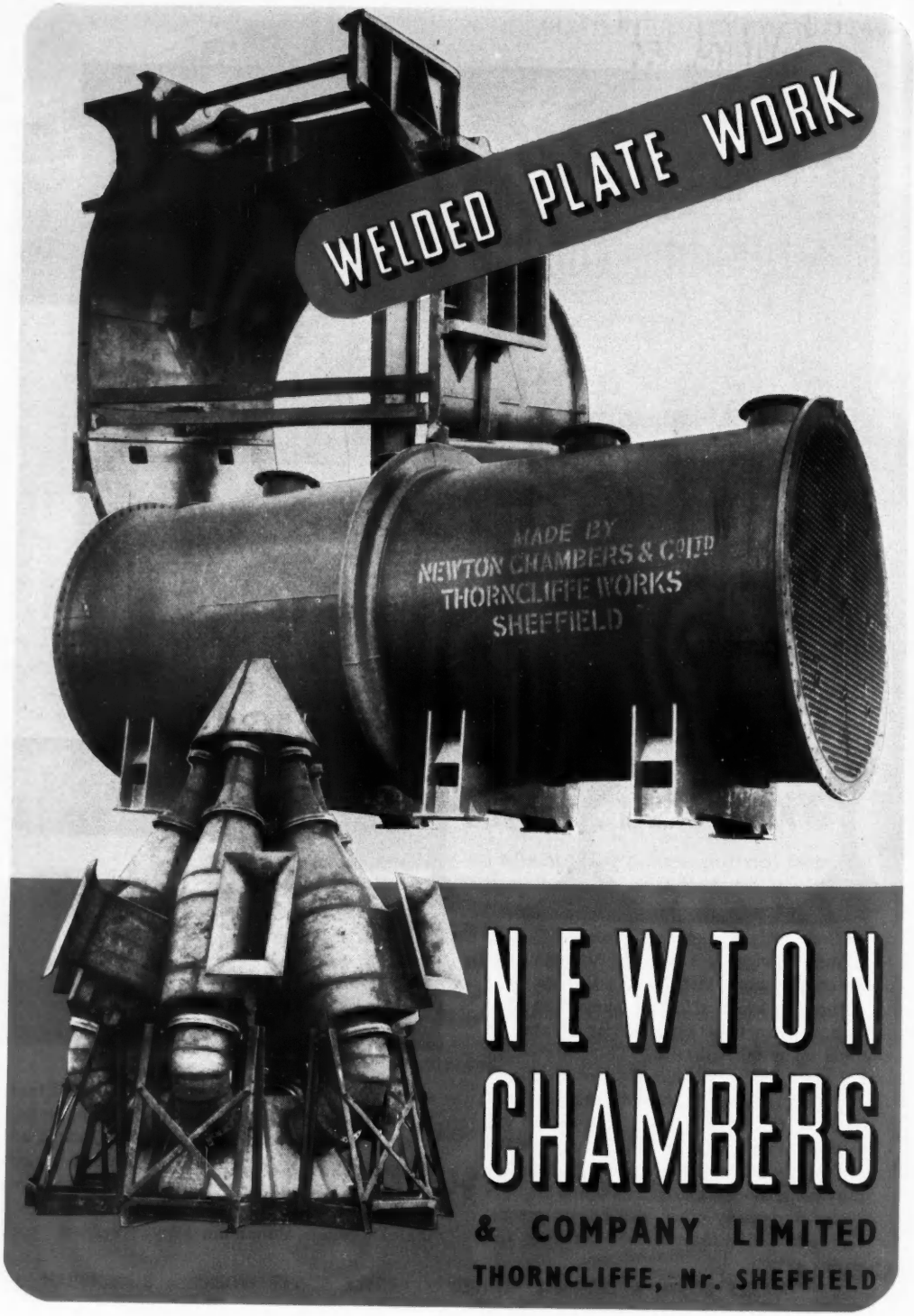
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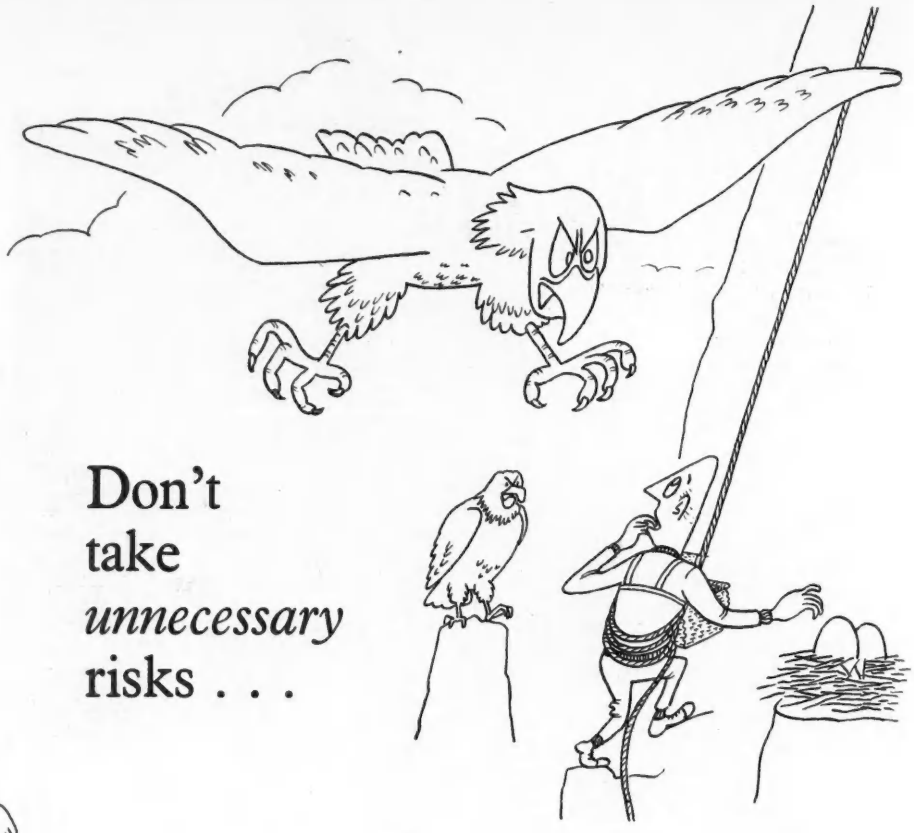

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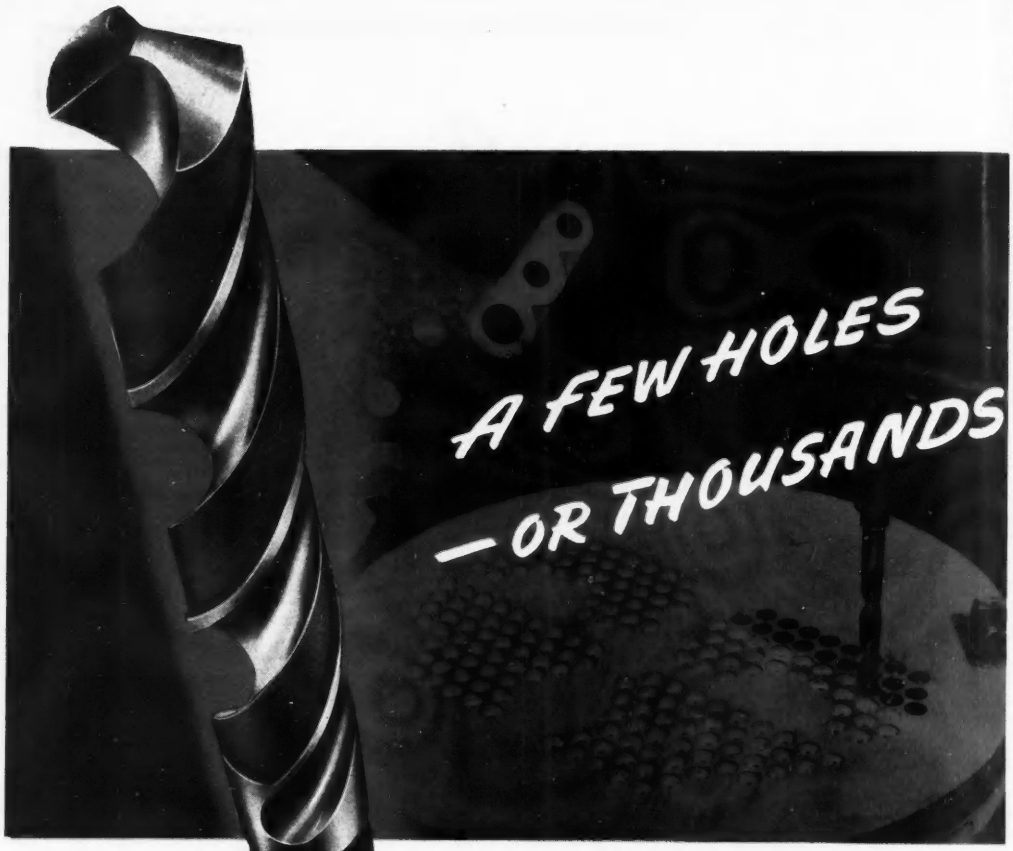

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	Maximum Stress t.s.i.	Yield Point t.s.i.	Elongation per cent
Pearlitic	37 min.	27 min.	1 min.
Pearlitic/ Ferritic	32 „	24 „	5 „
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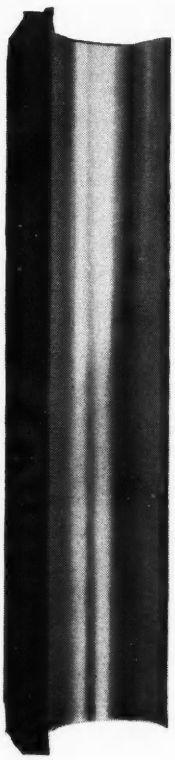
The process is the subject of patents and patent applications, and The Mond Nickel Company Limited has granted a number of manufacturing licences. For names of suppliers, write to :—



Pin lift arms in S.G. iron for moulding machine.

Ironer machine bed, weight 2 tons, in S.G. iron for single-roll machine. Properties include pressure-tightness in the steam heater passages with a high finish on the ironing face. ***(By courtesy of D.& J. Tullis Ltd.)***

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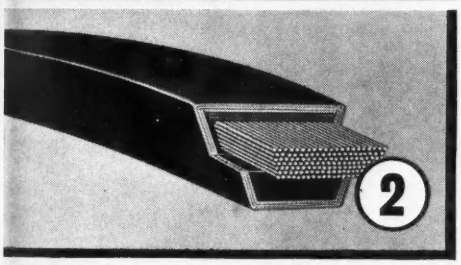

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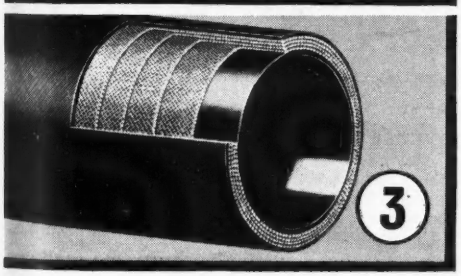

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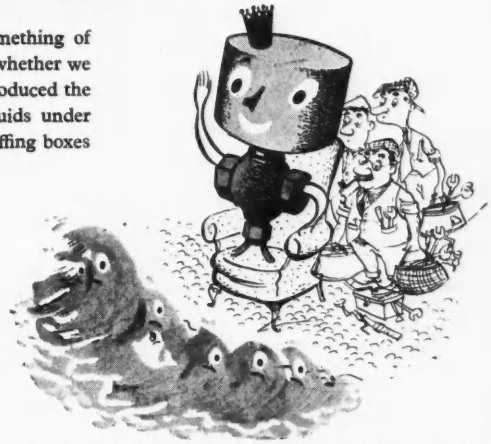

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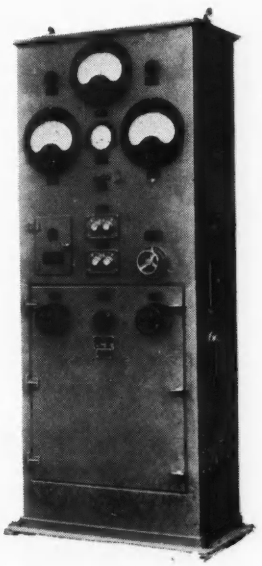

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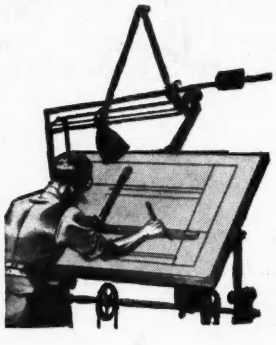

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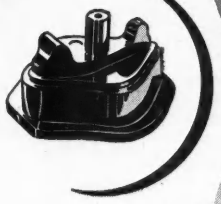

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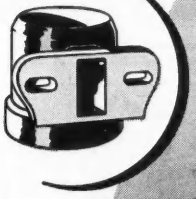

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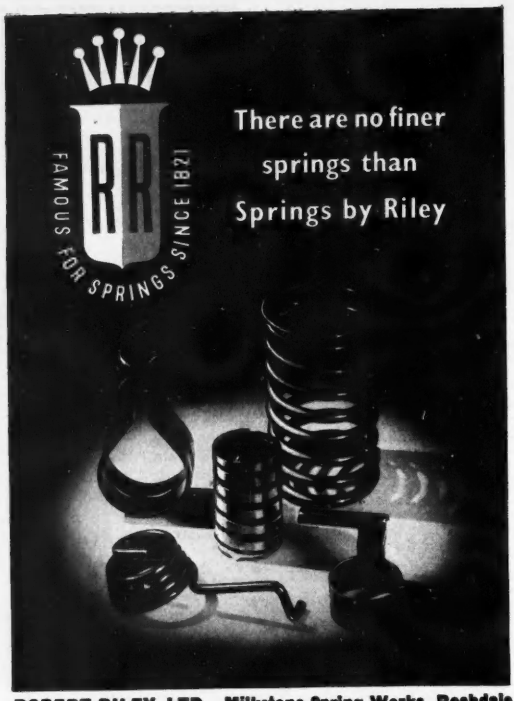

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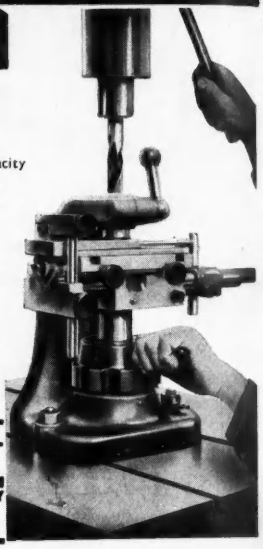

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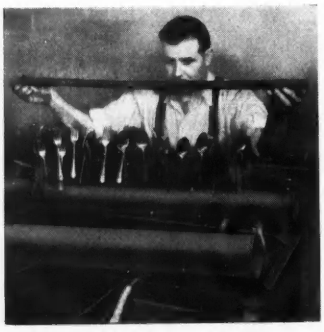

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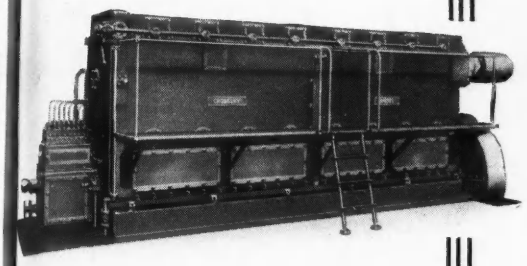

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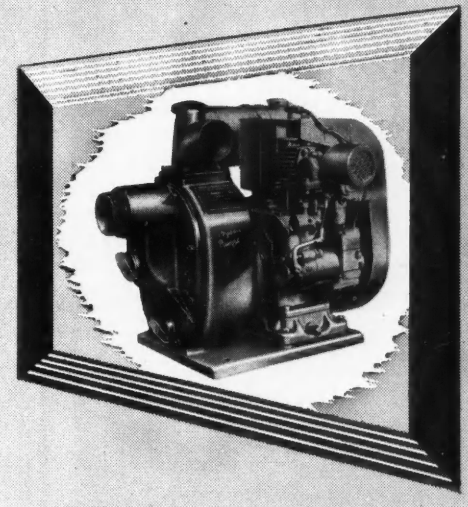

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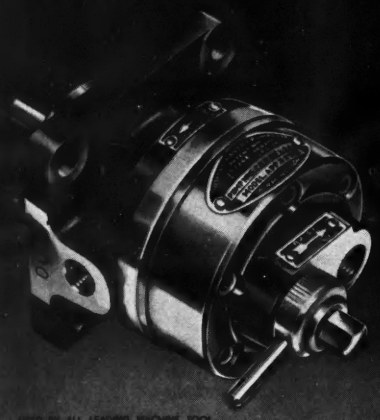

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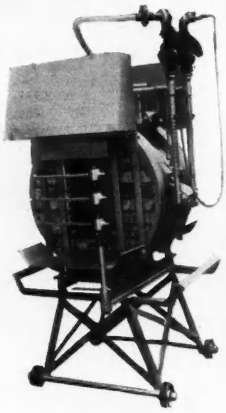

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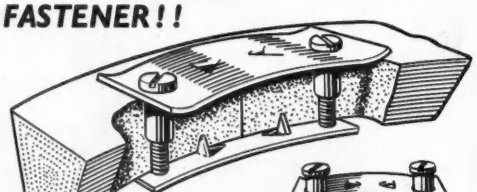

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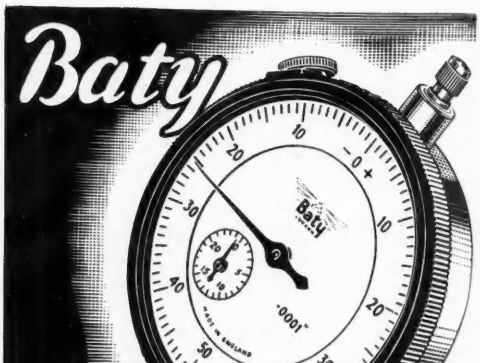

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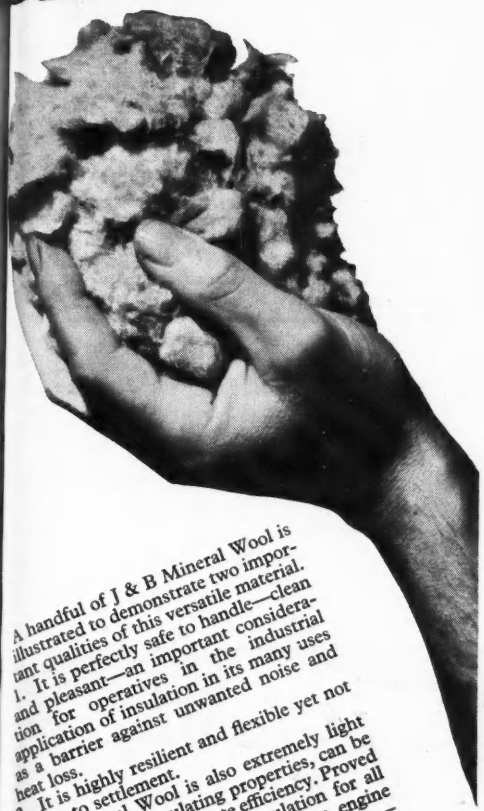

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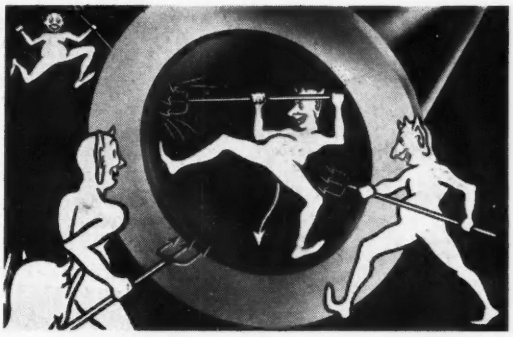

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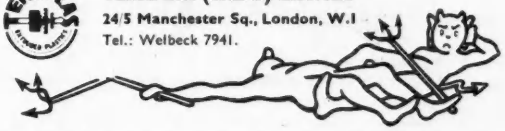

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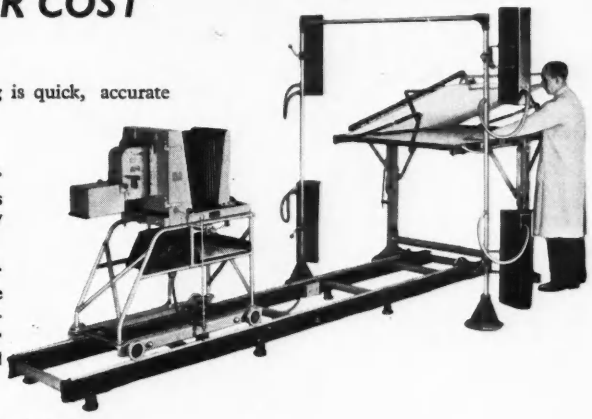

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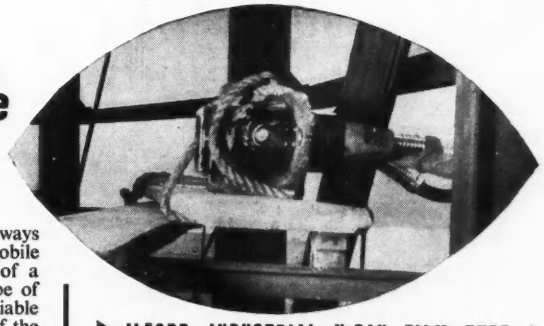

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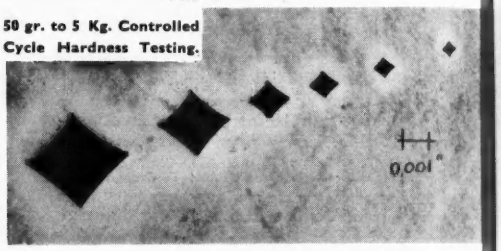

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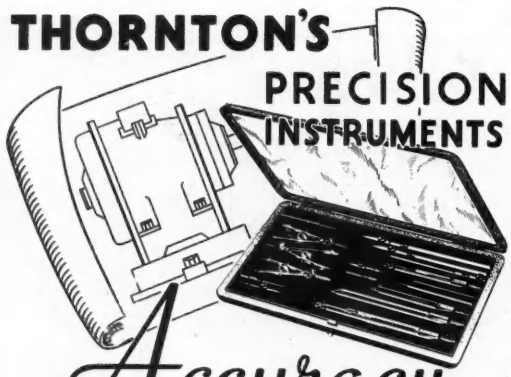

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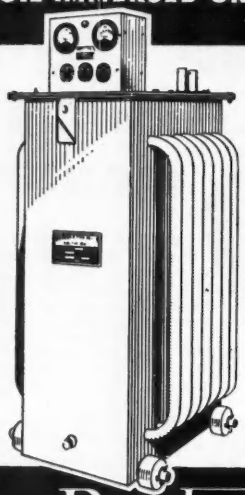

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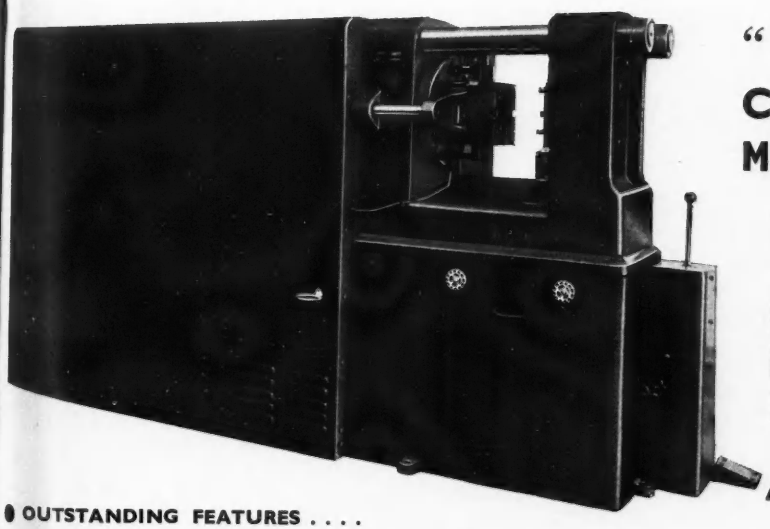

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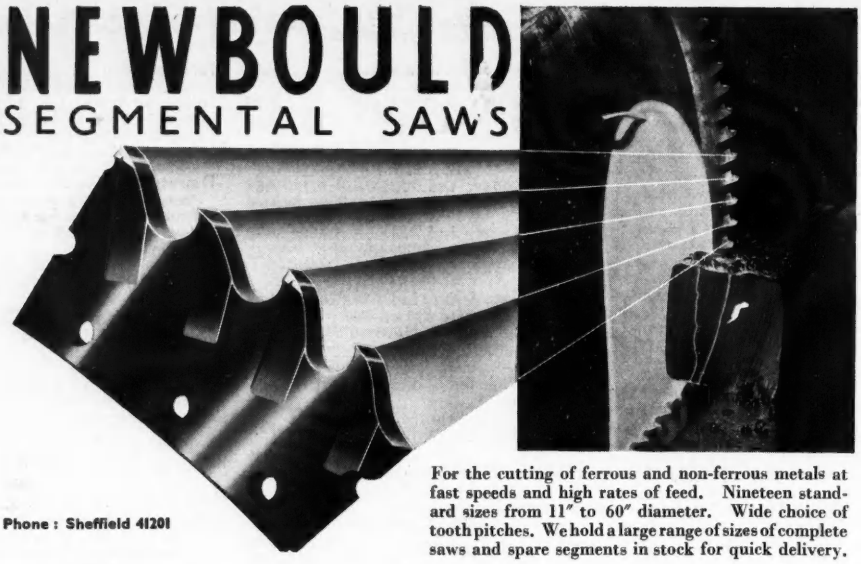

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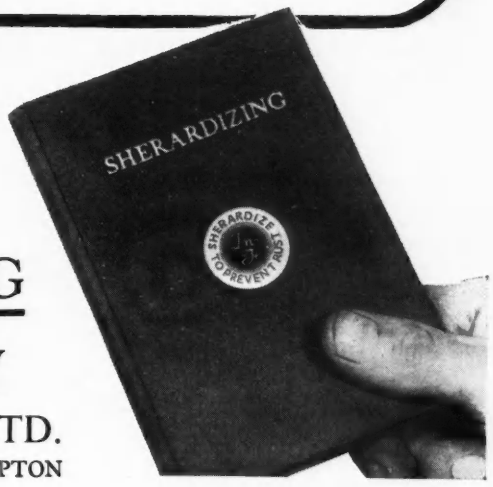

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